EXHIBIT C6

IN THE UNITED STATES DISTRICT COURT
FOR THE DISTRICT OF NEW JERSEY

IN RE: JOHNSON & JOHNSON TALCUM POWDER PRODUCTS MARKETING, SALES PRACTICES AND PRODUCTS LIABILITY LITIGATION ***THIS DOCUMENT RELATES TO ALL CASES***	**MDL NO. 16-2738 (FLW) (LHG)**

EXPERT REPORT OF ANN G. WYLIE, PHD FOR GENERAL CAUSATION *DAUBERT* HEARING

Date: February 25, 2019

Ann G. Wylie, Ph.D

Ann G. Wylie, Ph.D.

I. SUMMARY OF OPINIONS

I have been asked to provide my opinion in the form of an overview of the nature of talc, amphibole, and serpentine minerals associated in and around talc deposits. I will discuss the differences between amphibole particles that form as asbestos (asbestos fiber) and those that form from crushing rock (cleavage fragments) and the distinctions between these two forms of amphibole. I will describe the conditions necessary for mineral fiber to form, provide an overview of the ways in which talc forms and describe the evidence on the association of different talc ores with asbestos. I will also provide my perspectives on how regulatory analytical techniques have been used to incorrectly classify cleavage fragments as asbestos fibers.

The opinions expressed in this report are rendered with a reasonable degree of scientific certainty. Based on my education, training and experience as a geologist and my review of relevant information for this matter, I have reached the following conclusions and opinions:

A. Talc is a mineral and a component of cosmetic and industrial talc products. It is formed by alteration of Mg-rich rocks. Talc for cosmetic use is mined in only a few places because of the stringent requirements for the product.

B. Amphibole and serpentine are both common rock-forming minerals. Both are hydrated, both can be found in Mg-rich rocks, and both can be associated with talc ore. Both occur rarely as asbestos.

C. Amphiboles, talc (and other minerals) may form elongated fragments when they are broken during mining, mineral processing and rock and soil excavation. These fragments are not “asbestos,” nor “asbestiform” and they do not have the properties of asbestos.

D. Mineral fiber is uncommon. Amphiboles that form in the asbestiform habit (e.g., asbestos) exhibit special properties that are different than those same amphiboles that otherwise form in nature.

E. Many naturally occurring minerals will form elongated particles that meet regulatory criteria for fiber. Unfortunately, analytical protocols developed for occupational monitoring for airborne fiber during asbestos use and for determination of clean air after removal of asbestos from school buildings will produce false positives for mineral fiber when applied to rock powders. Regulatory criteria are broad and obscure the fundamental characteristics of asbestos.

F. Amphibole populations of asbestos fibers and cleavage fragments each have distinctive characteristics in their optical properties, dimensions and habits. The two types of microscopy used in making this distinction, polarized light microscopy (PLM) for optical properties and electron microscopy for dimensions and habit. The reports provided by plaintiffs’ experts Drs. Longo and Rigler examining the body powder products at issue in this litigation do not present evidence consistent with the optical properties or habit of asbestos.

G. PLM can be used effectively to detect and identify asbestos in talc products because there are optical properties that are characteristic of cleavage fragments and others that are characteristic of asbestos.

H. The photomicrographs found in Drs. Longo and Rigler's reports document the presence of cleavage fragments. Particles labeled as bundles do not have morphology consistent with that designation (i.e., they are not bundles).

I. Evidence of fiber bundles is lacking in Drs. Longo and Rigler's transmission electron microscopy (TEM) photomicrographs of tremolite and anthophyllite, despite the fact that the particles are labeled as bundles. There is a wide range in the width of particles identified as tremolite and anthophyllite, and the particle shapes are consistent with a population dominated by cleavage fragments.

J. In general, to determine if a particle is asbestiform, one cannot simply calculate its aspect ratio. Aspect ratio does not tell anything about actual size, only relative size. Aspect ratio has no dimension. Characteristic of both asbestos and cleavage fragments is an increase in aspect ratio with increasing length, i.e., longer elongated mineral particles (EMPs) have higher aspect ratios. Differences or similarities in aspect ratio frequencies may, therefore, be due to differences in length frequencies rather than habit.

K. TEM techniques do not readily distinguish between EMPs of talc and anthophyllite. PLM is the most reliable instrument to make this distinction.

L. Based on their geologic settings, reports from mine geologists and literature descriptions of the ore deposits providing cosmetic talc for the relevant body powder, it is unlikely that asbestos could be found in the talc products from these mines.

M. The formation of talc does not require nor favor the formation of asbestos in the ore.

N. In rushing to deal with the asbestos problem of the 1960s, the Occupational Safety and Health Administration (OSHA) oversimplified its regulations, and in so doing, confused the distinctions between asbestos and cleavage fragments. Today, all regulatory language specifies the asbestiform habit, and by policy and practice regulatory bodies do not regulate cleavage fragment EMPs as asbestos.

II. BACKGROUND AND QUALIFICATIONS

I graduated *cum laude* from Wellesley College with a degree in Geology in 1966. I received my Ph.D. from Columbia University in 1972 with a major in economic geology, and minors in mineralogy, petrology and mining engineering. I was appointed Assistant Professor by the Department of Agronomy at the University of Maryland in 1972, but one year later the appointment was transferred to the newly formed Department of Geology. I retired as Professor of Geology and Distinguished Scholar Teacher in 2014, but continue to hold an appointment as Professor Emerita. In addition to my academic appointments, between 2000 and 2014, I held a variety of senior level administrative appointments, including Assistant President and Chief of Staff, Vice President for Administrative Affairs, and Senior Vice President and Provost.

Between 1979 and 2017, I published, among others, 38 articles on talc, amphibole and/or asbestos in highly regarded peer-reviewed publications. My curriculum vitae is attached as Exhibit A.

My most recent papers include:

> Wylie, A and P Candela (2015). Methodologies for determining the sources, characteristics, distribution, and abundance of asbestiform and non-asbestiform amphibole and serpentine in ambient air and water. *Journal of Toxicology and Environmental Health*, Part B: Critical Reviews. 18: 1-42.
>
> Wylie, A.G. (2016). Amphiboles: Fibers, fragments and mesothelioma. *Canadian Mineralogist* 54(6): 1403-1435.
>
> Kerrigan, RJ, Candela PA, Piccoli PM, Frank M and Wylie A (2017). Olivine + quartz + water ± HCl at mid-crustal conditions: controls on the growth of fibrous talc as determined from hydrothermal diamond anvil cell experiments. *Canadian Mineralogist*. 55(1): 101-113
>
> Wylie, A.G. (2017). Mineralogy of Asbestos and fibrous erionite. In *Current Cancer Research: Asbestos and Mesothelioma*, Joseph Testa Ed. Springer, Heidelberg pp, 11-41.

I am being compensated at a rate of $350 per hour for my expert work in this litigation.

III. OPINIONS

A. What is talc?

Summary: Talc is a mineral and a component of cosmetic and industrial talc products. It is formed by alteration of Mg-rich rocks. Talc for cosmetic use is mined in only a few places because of the stringent requirements for the product.

A **mineral name** specifies 1) the chemical composition, and 2) the atomic structure; together these must be unique to be called by a mineral name.

Talc is hydrated magnesium silicate (meaning it contains water, magnesium and silicon) with a chemical formula of $Mg_3Si_4O_{10}(OH)_2$. It belongs to a group of minerals known as sheet silicates, due to the sheet-like arrangement of the atoms in the structure.

Talc is the softest mineral known, and it can be broken easily with your fingernail into flat plate-like particles; the particles are referred to as "platy." These smooth, flat particles give the material a greasy or slippery feel and make it suitable for body powder. Talc may also form irregularly shaped or even elongated prismatic particles, but these are less desirable for cosmetic talc. Mineral talc can also form as fibers. In New York State, for example, the fibers are asbestiform and probably formed from the alteration of anthophyllite. Talc fiber may also form directly from metamorphic fluids without alteration from an amphibole (Kerrigan et al 2017). This type of talc fiber is a normal, but not abundant, component of most talc ore.

Confusingly, the term “talc” is also used to refer to mineral products containing the mineral talc in proportions that vary from about 30 to 100 percent. I will use “talc” to mean the mineral, and specify **industrial or cosmetic talc** when referring to a mineral product that contains it. **Talc ore** means the rock from which the talc was extracted.

Talc ore is formed by **hydrothermal alteration of other minerals during metamorphism**. This means that at some time in the geologic past, elevated temperature and fluid pressure prevailed in rock, resulting in chemical reactions with one set of minerals changing into (metamorphosing) another set. Hydrothermal means hot water and metamorphism means mineral transformations. Talc results if the starting rock is of the right composition, water is present and the right temperature and pressure are in place.

Talc ore is mined for both industrial and cosmetic use, but from different ore bodies and in different mines. Industrial talc used in paint, plastic, rubber and ceramic tile, for example, is unsuitable for cosmetic purposes due to its physical properties and mineral composition. Industrial talc products vary widely in color, texture and talc content. In Texas, for example, the talc ore that is mined for ceramics is black. Some industrial talc contains < 50% mineral talc.

Talc ore used for cosmetic purposes, however, is different. For talc to be sold as body powder, it must meet specifications in color, texture, mineral composition and absorbance, which ore from only a few mines can provide. For example, cosmetic talc product normally contains ≥95% mineral talc, is very white and must be substantially free of quartz. Talc ores from which a product of this purity can be extracted economically are uncommon.

B. What are amphibole and serpentine minerals?

Summary. Amphibole and serpentine are both common rock-forming minerals. Both are hydrated, both can be found in Mg-rich rocks, and both can be associated with talc ore. They occur rarely as asbestos.

1. Amphibole.

Amphibole minerals are a family of double-chain hydrated silicate minerals. Amphiboles are referred to as rock-forming minerals because of their abundance. Overall, amphibole can be found in six to ten percent of the crustal rock of the contiguous US (Wylie and Candela, 2015), but in some areas it is more abundant. Amphibole is most common in metamorphic rocks and metamorphic rocks are common in old and new mountain belts. Amphiboles are also found in the oldest rocks that form the continental cores, and in and around intrusive igneous rock, such as granite, which crystallizes from liquids (magma). Figure 1 shows the distribution of igneous and metamorphic rocks in the US that may contain amphibole and serpentine.

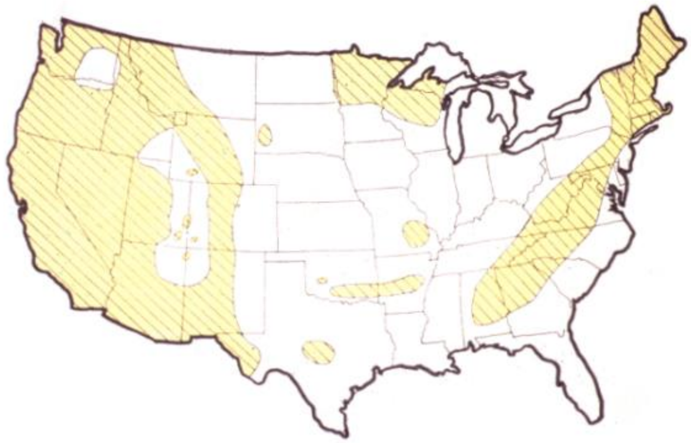


Figure 1. This map was produced by Kuryvial et al (1974), US EPA. It shows the distribution of rocks likely to contain amphibole and serpentine.

Amphiboles are composed of the most common elements found in the crust of the earth. These elements and abundances are: oxygen (46.6%), silicon (27.7%), aluminum (8.2%), iron (5.0%), calcium (3.6%), potassium (2.8%), sodium (2.6%) and magnesium (2.1%). (Rudnick and Gao, 2003).

Amphiboles are so common in some rocks that the names of several main rock categories refer to the amphibole component. These include amphibolite, greenstone (green amphibole), and blue schist (blue amphibole). Amphiboles also occur in smaller quantities in marble and granite (e.g., the dark streaks in granite used for countertop materials and building stone commonly contains amphibole), or in large quantities in some metamorphosed banded iron formations, the major ore of iron worldwide. Amphiboles may also occur in soils formed from underlying amphibole containing rock and in deposits left by glaciers. Amphibole-rich rock is mined for building roads and rail lines and has been used in a crushed form on “clay” tennis courts. Mines of many different commodities penetrate rock containing amphibole, including iron, gold, talc, copper and crushed stone. Amphibole may be a common component of dimension stone for floor tiles and it forms nephrite, the name for common jade.

The amphibole minerals most commonly associated with talc are tremolite, actinolite and anthophyllite. The ideal formulas are $Ca_2(Mg,Fe)_5Si_8O_{22}(OH)_2$ for the tremolite-actinolite continuum (nomenclature based on Mg/(Mg+Fe)), and anthophyllite, $Mg_2(Mg,Fe)_5Si_8O_{22}(OH)_2$. Nomenclature of these amphiboles is formally determined by precise chemical analysis and standards established by the International Mineralogical Association.

2. Serpentine.

Like talc, serpentine is formed by alteration of ultramafic rock and carbonates, and like talc, it is a hydrated magnesium sheet silicate. Serpentine contains 13% water, while talc contains about 5%. (Veblen and Wylie, 1993).

There are three serpentine minerals that have the same ideal chemical formula ($Mg_3Si_2O_5(OH)_4$) and all have a sheet-like atomic structure. However, they crystallize in three distinct atomic arrangements. The three forms are called **chrysotile, antigorite and lizardite**. Chrysotile forms from rolled sheets forming tubes that are about 0.025 µm in diameter and have an inner hollow tube of about 0.005 µm (Veblen and Wylie 1993); these are **fibrils** of chrysotile asbestos.

Serpentine is the major mineral in the rock **serpentinite**. Serpentinites are common throughout the Appalachian Mountains and in California in large blocks, varying in size from feet to miles. In these occurrences, serpentinite was thought to have originated as a piece of ocean crust thrust onto the continent during mountain building processes associated with plate tectonics.

Serpentine may also form as a mineral component of some metamorphosed carbonate rocks.

C. What is a mineral fiber and what is "asbestos"?

Summary: Mineral fiber is uncommon. Amphiboles that form in the asbestiform habit (e.g., asbestos) exhibit special properties that are different than those same amphiboles that otherwise form in nature.

In most dictionaries, the definition of fiber is 'threadlike'. When minerals form in nature as bundles of easily separable, long, very thin, very narrow crystals that are flexible (high tensile strength), the description "threadlike" may apply. Such material is called asbestos. Under U.S. regulatory policy, the term "asbestos" has been applied only to six asbestiform minerals mined and sold as "asbestos," namely chrysotile and the asbestiform varieties of actinolite, grunerite (amosite), anthophyllite, riebeckite (crocidolite) and tremolite.

Asbestos is not a mineral, but a **set** of durable, chemical and heat resistant minerals that form in the **asbestiform habit**. Habit is a mineralogical term specifying the physical form a mineral takes when it forms (grows) in nature, e.g., globular, granular, prismatic, fibrous. The habit of growth of asbestos is referred to as **asbestiform. This means that the occurrence of the mineral is as** narrow, fairly uniform single crystals called **fibrils** occurring in bundles (common) and matted masses (rare). Asbestos is easily separated into fibrils and fiber bundles with hand pressure.

The term "fibrous" is much broader than asbestiform, which it includes. Fibrous also applies to wide, brittle, glassy fibers called byssolite, and even materials that look like they may be made up of fiber are referred to with this term.

The habit of asbestos is well illustrated in Figure 2 below. The very narrow fibers and fibrils are not connected laterally to each other so they can scatter and separate easily. Note the similarity in the width of the fibrils. Amphibole asbestos almost always occurs in amphibole bearing rock and chrysotile asbestos almost always occurs in serpentinite. However, only about 0.1% of amphibole minerals are formed in the asbestiform habit and occurrences are localized and uncommon (Wylie and Candela, 2015).

Mineral fiber forms in nature only under very special circumstances. An environment containing water-rich fluid, saturated with the mineral in solution, and a space in which to grow fiber unimpeded is necessary for the rapid precipitation of very fine fibrils of asbestos. Such environments are limited in scope and time.

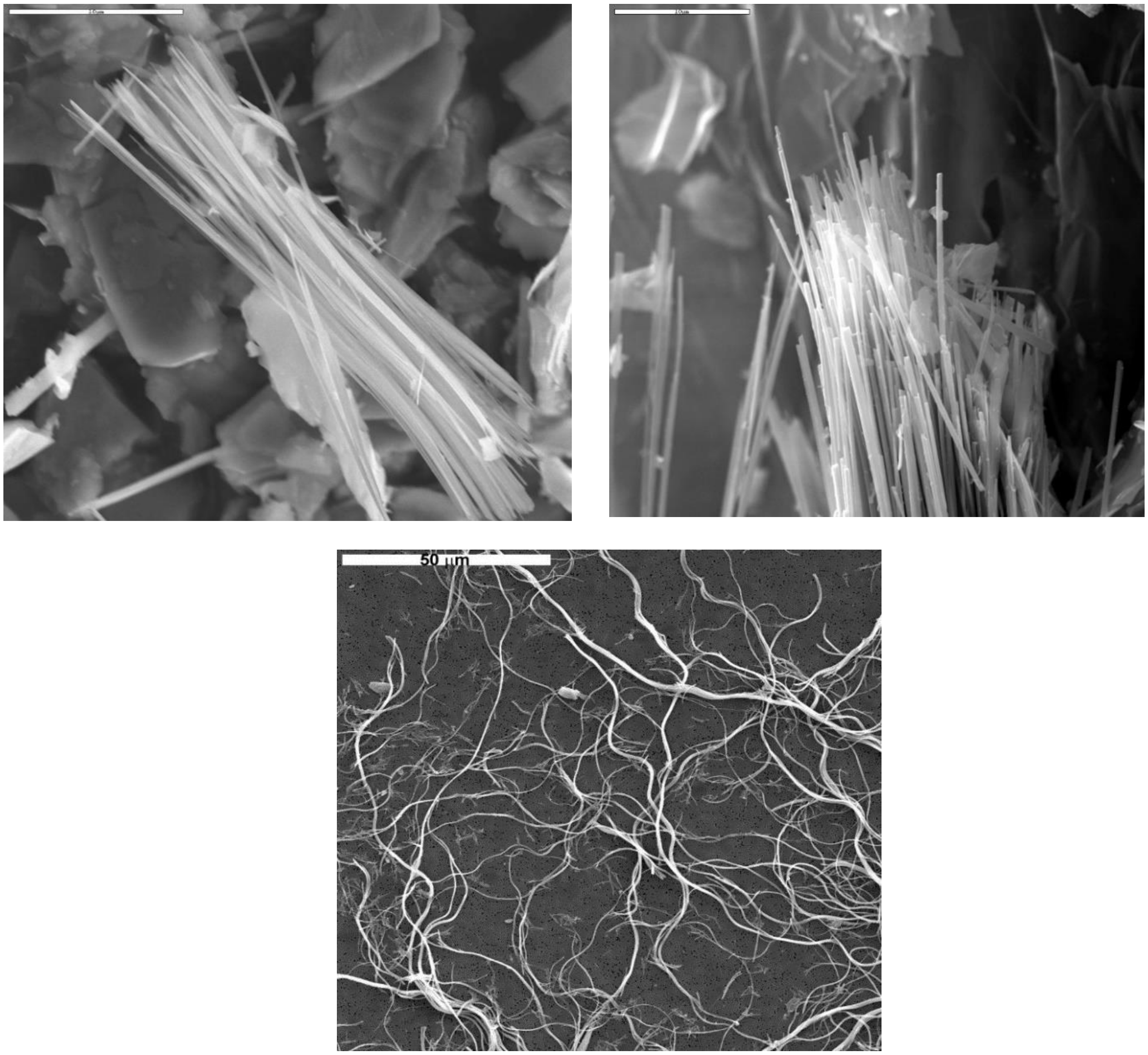


Figure 2. Asbestos from USGS (Usgsprobfe.cr.usgs.gov/picts2.html): a) tremolite asbestos, Death Valley California; b) Richterite-winchite asbestos, Libby MT; and c) UICC chrysotile A

In regions where heat flow is high and volcanism is active, there will likely be asbestiform mineral fiber. For example, mineral fiber is common in areas with Cenozoic (last 65 million years) volcanism, such as Turkey, Oregon and Nevada, where asbestiform fibers of the mineral erionite formed in altered volcanic glasses and tuffs, or southern Italy, where fibers of the amphibole fluoro-edenite formed in seams and cavities in volcanic rocks around Mt. Etna. (Gianfagna et al., 2007). This is not a normal environment for talc deposits.

Asbestiform fiber can form when fluid pressures are very high because of tectonics (mountain building), as evidenced by the fibrous masses of amphibole glaucophane winding around blocks of other rock in the blue schist of California that formed during subduction of the Pacific Plate under North America, or, the mountain of very short mass fiber chrysotile that occurs at the Coalinga deposit of California. The **mass fiber** anthophyllite-asbestos ores at Paakkila, Finland, and elsewhere were probably formed by high fluid pressure events during retrograde metamorphism.

Asbestiform mineral fiber can form when rocks are under tension and hot water carrying dissolved components of amphibole or serpentine is available. This is the most common environment for the formation of asbestos fiber. This may be expansion upward as over burden is removed or the crust thins, in faults that pull rock apart, and in the axes of folds. Fiber that forms under these circumstances occurs in well-defined planes called seams or veins containing fibers that grow perpendicular to the wall of the seam, parallel to the direction of expansion. This fiber is called **cross fiber**. In the event that the movement involved lateral motion, mineral fiber may form parallel to the wall of the seam, and this is referred to as **slip fiber**. Amosite and crocidolite ores are from veins, primarily cross fiber. Most chrysotile deposits are also cross fiber (with the notable exception of the Coalinga mountain in California). Tremolite asbestos and actinolite asbestos also form in cross fiber and slip fiber veins.

Figure 3 below includes pictures of "asbestiform" ice. Ice is a mineral. I took the first picture while hiking in the Catoctin Mountains. It had been quite cold for many days and there had been some snow. The day before this was taken, the day was warm, and the upper several inches of soil had thawed, leaving a very muddy surface layer in some places. The next night, the temperature dropped quickly and the mud froze with fibers of ice forming rapidly in the mud.

Not everything is understood about how mineral fiber forms, however. For example, it was recently discovered that the form of fibrous ice shown in Figure 3(b) grows on a substrate of wood. The individual fibers remained as separate fibrils due to a chemical released by fungus living in the wood. While fungus may not be implicated in the origin of asbestos, the chemistry of the fluids from which asbestos forms likely influences fiber formation in similar ways. In fibrous ice, individual fibers of ice share a common axis of elongation, but because of their rapid nucleation and growth, or in one case, the presence of fungus, fibers are not connected to each other, so they separate readily. Fibrous ice, like asbestos, only forms in very particular environments. Unlike asbestos, fibrous ice lacks durability, so while it is asbestiform in habit, it is not asbestos.

Figure 3. Fibrous Ice. a) Ice from saturated muds, Catoctin Mountains, MD. b) Fibrous ice formed in forest in Germany (from Eos. V 96. Number 16. 2015, p. 3)

Importantly, asbestos fiber exhibits many properties different from those characteristic of fragments of the same mineral, even if the particles are of roughly the same length. Fibers of

asbestos are narrower than cleavage fragments of the same length. Fibers of asbestos possess high tensile strength and flexibility, both attributable to the narrowness of fibrils. High tensile strength promotes the preservation of long fiber during crushing. Bundles of even a few fibrils will exhibit properties that are anomalous when viewed by polarized light microscopy (Verkouteren and Wylie 2002).

D. What are cleavage fragments?

Summary: Amphiboles, talc (and other minerals) may form elongated cleavage fragments when rocks are broken during mining, mineral processing and rock and soil excavation. These fragments are not "asbestos," nor "asbestiform," and they do not have the properties of asbestos.

Amphiboles possess in their atomic structure two planes that have weaker bonds than other directions in the lattice, meaning they will break, or "cleave," preferentially along these weak planes. For this reason, when amphibole-bearing rock is crushed during mining and mineral processing, amphibole of all compositions will form elongated fragments (EMPs). These are referred to as **cleavage fragments**, cleavage because they were "cleaved" from a larger piece of amphibole, and "fragment" because they were formed by fracture. Amphibole, like almost all rock, is brittle unless asbestiform, and it readily forms EMPs when crushed.

For visual reference, Figure 4 is non-asbestiform amphibole EMPs of the amphibole riebeckite, formed by crushing more massive material. The image in Figure 5 is reproduced from the United States Geological Survey's website (usgsprobe.cr.usgs.gov/picts2.html). The particles shown are non-asbestiform amphibole, in this case tremolite, which was crushed, forming EMPs. The sizes and shapes of the amphibole cleavage fragments depicted in Figures 4 and 5 are similar to cleavage fragments formed by crushing many common, durable, silicate minerals.

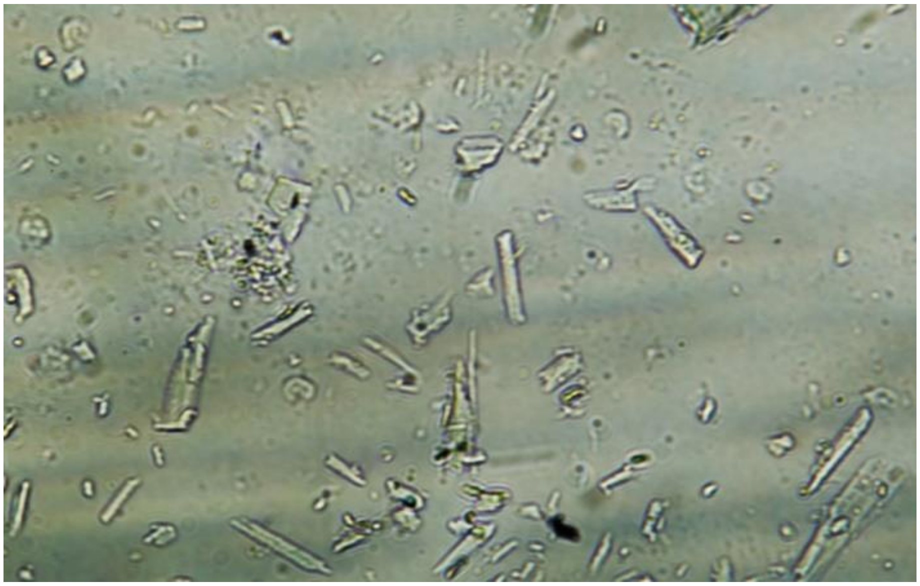


Figure 4. Cleavage fragments of amphibole riebeckite as seen by PLM. Largest particles are about 20μm in length.

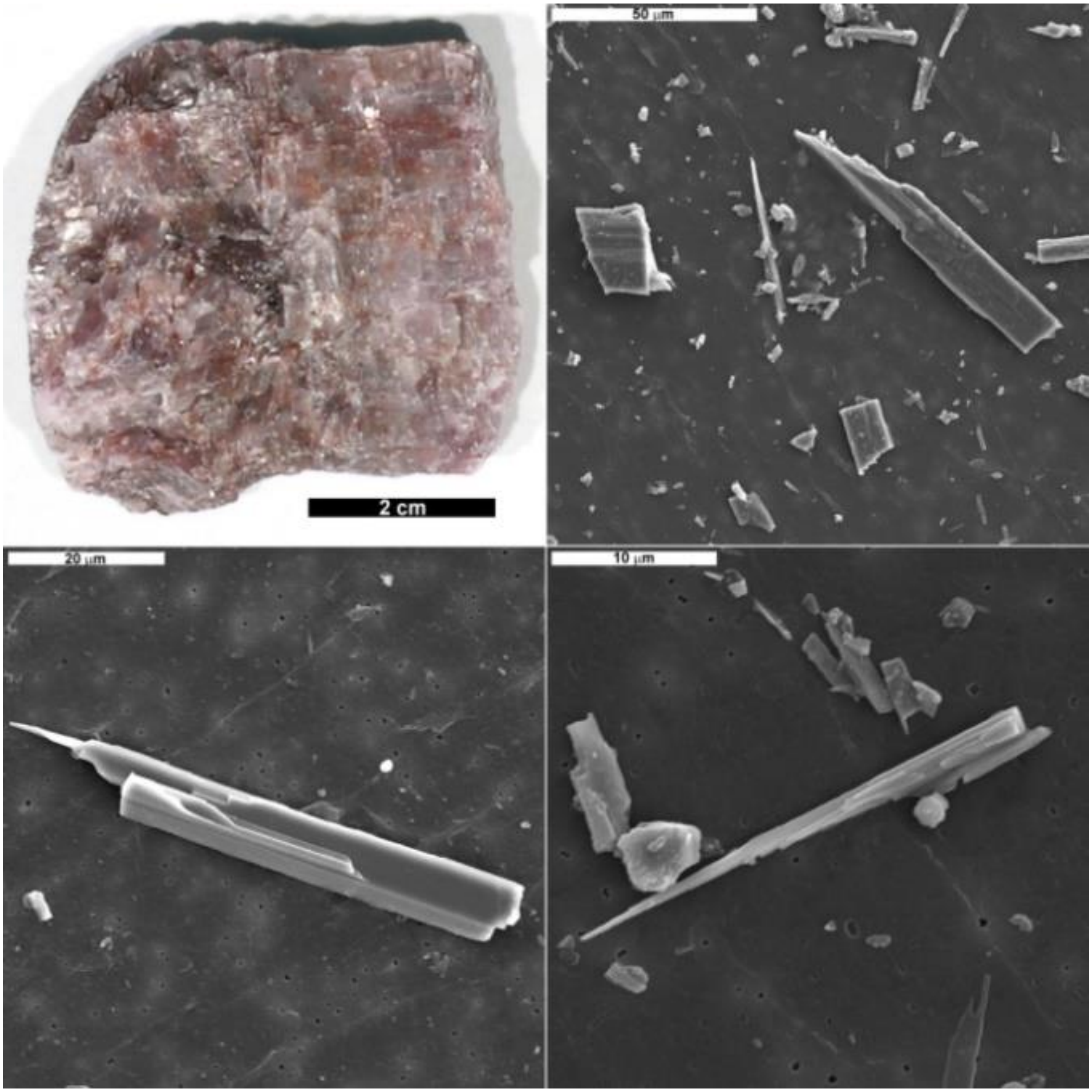


Figure 5. Tremolite cleavage fragments viewed by SEM (USGS).

Cleavage fragments are elongated chunks of rock and are generally wider than asbestos fiber of the same composition and length. Cleavage fragments are brittle. They are never "threadlike." They do not exhibit enhanced tensile strength. Mineral fiber cannot be produced from cleavage fragments. I am unaware of any literature that supports the notion that non-asbestiform minerals such as tremolite could be modified during processing and turned into asbestos. If a mineral does not form as fibers in nature, it cannot form the very thin fibers characteristic of asbestos by crushing it. Moreover, while asbestos fiber bundles may disaggregate after entering the respiratory system, resulting in increases in the dose of fiber over time, cleavage fragments do not disaggregate after entering the body because they are single structures.

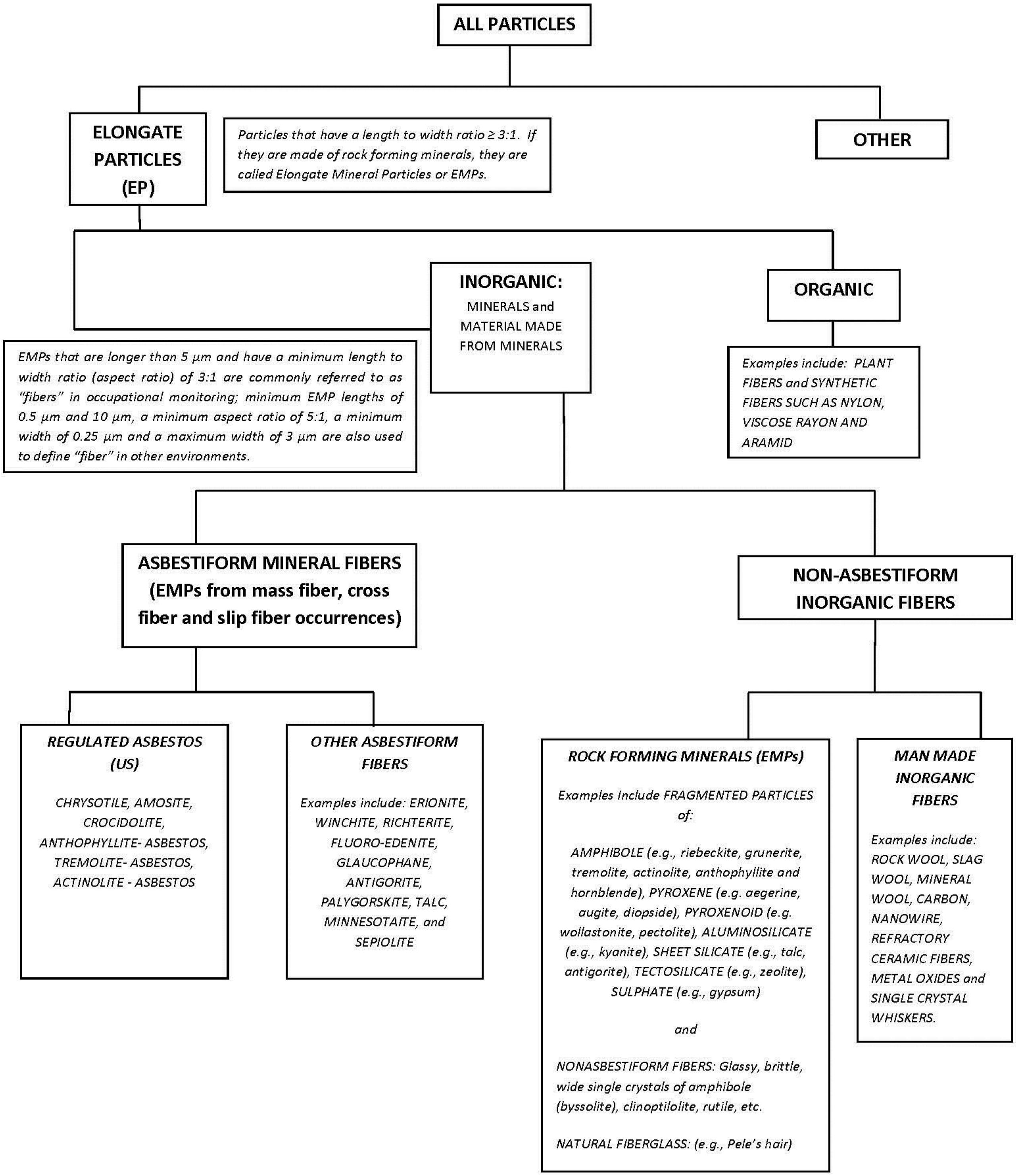
E. Regulatory Terminology: Fibers and elongated mineral particles (EMPs).

Summary: Many naturally occurring minerals will form elongated particles that meet regulatory criteria for fiber. Unfortunately, analytical protocols developed for occupational monitoring and for determination of clean air after removal of asbestos from school buildings, will produce false positives when applied to durable EMPs in rock powders. The regulatory criteria are broad and obscure the fundamental characteristics of asbestos.

Federal protocols for monitoring known occupational exposure to asbestos specify the term **fiber** to mean any airborne particle that is greater than 5 µm in length that has a length to width ratio of at least 3:1. For assessing the cleanliness of a building after asbestos removal, federal AHERA (US EPA 2002) rules require that airborne asbestos fibers longer than 0.5 µm with a length to width ratio of at least five (5:1) be counted. Other federally recognized methods for monitoring asbestos use other fiber definitions in exposure assessments. In short, there are multiple definitions of the term fiber used in regulatory protocols; none describes thread-like asbestos mineral fiber very well (Candela and Wylie, 2015).

NIOSH introduced the term elongate mineral particles (EMPs**)** in 2006 (NIOSH, 2006). An EMP that was formerly referred to as fiber based on dimensions is now called an elongated mineral particle. EMP is a neutral term because it assumes nothing about the manner in which it formed: growth or fracture. It may be an elongated rock fragment formed during crushing rock (cleavage fragment) or liberated during soil formation, or it may be asbestos. Particles counted by occupational monitoring protocols for asbestos are not necessarily mineral fibers, but they are all EMPs.

The chart on the next page shows the types of material that qualify as EMPs. It illustrates the fact that many common minerals can form EMPs and that many particles could be incorrectly classified as mineral fiber by federal asbestos counting criteria. Because they are common, miners of many different materials have routinely been exposed to EMPs. This Table is published in Toxicology and Applied Pharmacology (Weill et al., 2018).


ALL PARTICLES
ELONGATE PARTICLES (EP)
Particles that have a length to width ratio ≥ 3:1. If they are made of rock forming minerals, they are called Elongate Mineral Particles or EMPs.
OTHER
INORGANIC: MINERALS and MATERIAL MADE FROM MINERALS
ORGANIC
EMPs that are longer than 5 µm and have a minimum length to width ratio (aspect ratio) of 3:1 are commonly referred to as "fibers" in occupational monitoring; minimum EMP lengths of 0.5 µm and 10 µm, a minimum aspect ratio of 5:1, a minimum width of 0.25 µm and a maximum width of 3 µm are also used to define "fiber" in other environments.
Examples include: PLANT FIBERS and SYNTHETIC FIBERS SUCH AS NYLON, VISCOSE RAYON AND ARAMID
ASBESTIFORM MINERAL FIBERS (EMPs from mass fiber, cross fiber and slip fiber occurrences)
NON-ASBESTIFORM INORGANIC FIBERS
REGULATED ASBESTOS (US)
CHRYSOTILE, AMOSITE, CROCIDOLITE, ANTHOPHYLLITE- ASBESTOS, TREMOLITE- ASBESTOS, ACTINOLITE - ASBESTOS
OTHER ASBESTIFORM FIBERS
Examples include: ERIONITE, WINCHITE, RICHTERITE, FLUORO-EDENITE, GLAUCOPHANE, ANTIGORITE, PALYGORSKITE, TALC, MINNESOTAITE, and SEPIOLITE
ROCK FORMING MINERALS (EMPs)
Examples Include FRAGMENTED PARTICLES of:
AMPHIBOLE (e.g., riebeckite, grunerite, tremolite, actinolite, anthophyllite and hornblende), PYROXENE (e.g. aegerine, augite, diopside), PYROXENOID (e.g. wollastonite, pectolite), ALUMINOSILICATE (e.g., kyanite), SHEET SILICATE (e.g., talc, antigorite), TECTOSILICATE (e.g., zeolite), SULPHATE (e.g., gypsum)
and
NONASBESTIFORM FIBERS: Glassy, brittle, wide single crystals of amphibole (byssolite), clinoptilolite, rutile, etc.
NATURAL FIBERGLASS: (e.g., Pele's hair)
MAN MADE INORGANIC FIBERS
Examples include: ROCK WOOL, SLAG WOOL, MINERAL WOOL, CARBON, NANOWIRE, REFRACTORY CERAMIC FIBERS, METAL OXIDES and SINGLE CRYSTAL WHISKERS.

F. How to distinguish cleavage fragments from asbestiform fiber by microscopy.

Summary: Amphibole populations of asbestos fibers and cleavage fragments each have distinctive characteristics in their optical properties, dimensions and habits. The two types of microscopy used in making this distinction are: polarized light microscopy for optical properties and habit and electron microscopy for dimensions and habit. The reports provided by plaintiffs' experts Drs. Longo and Rigler examining Johnson's Baby Powder and Shower to Shower *do not present evidence based on optical properties and habit for a population of asbestos fibers.*

The distinction between cleavage fragments and asbestiform fibers is widely understood by science, industry and government. For example, the distinction is made by OSHA, which, by policy, regulates only fibers and not cleavage fragments (Crane, 2018). As discussed in the section entitled "Initial regulation of asbestos," below, other federal agencies also make the distinction in policy. Unfortunately, when OSHA removed cleavage fragments from asbestos regulation in 1993, it did not mandate a method to differentiate them from fiber, essentially leaving it up to others to sort out. OSHA's regulatory approach is consistent with counting EMPs as asbestos **only** when there is evidence of asbestos in the workplace already. In other words, OSHA do not follow its counting protocol as a definition of fiber because it is overly broad and inconsistent with its acknowledgement that non-asbestiform amphibole is not covered by its regulations.

Despite the lack of regulatory guidance, scientists have developed approaches for distinguishing between cleavage fragments and asbestiform fiber by employing all types of **microscopy** to look at populations of particles in mineral powders. While a single particle observed by microscopy might be confidently called a fiber or fiber bundle or fragment because of some defining characteristic(s), other particles cannot so easily be labeled, and must be viewed as part of a population of particles. The criteria for distinguishing mineral fiber from mineral fragments are different and complementary depending on what type of microscopy is being used: polarized light microscopy or electron microscopy. Each is explained below.

1. Polarized light microscopy (PLM).

Summary: Polarized light microscopy (PLM) can be used effectively to detect and identify asbestos in talc products because there are optical properties characteristic of cleavage fragments and other characteristics of asbestos fibers.

PLM employs plane polarized light to examine minerals. PLM is the primary tool used by geologists today to study rocks and rock powders, as it has been for a hundred years. In the study of powders, the samples are mounted in immersion oils of known index of refraction. Because minerals are crystalline, possessing a well-ordered arrangement of atoms, they will interact with polarized light in ways that change the nature of the light. These changes are referred to as optical properties. The optical properties of thousands of minerals are well documented and together they form a unique set that enables identification of most silicate and carbonate minerals. PLM is a powerful tool for the examination of talc products for asbestos and the identification of the minerals that compose it.

The ideal particle size for powdered minerals to be studied by polarized light microscopy is > 1 to about 150 µm. Powdered talc I have seen ranges in size from about 1 to 200 µm. Normally, it has passed through a 200 mesh sieve, making 74 µm the maximum middle dimension of particles in most cosmetic talc. My own examinations of body powders have found abundant large particles that are easy to study by polarized light microscopy. **It is these large particles that contain virtually all the mass of a powdered sample.**

The mineral forming EMPs can be identified by a set of well-established optical properties, and if asbestiform, bundles of even a few fibrils will exhibit optical properties that are anomalous (Verkouteren and Wylie, 2002). Figure 6 shows two EMPs photographed at the same magnification. Both are amphibole, but one is asbestos and one is a cleavage fragment. These particles typify their respective groups.

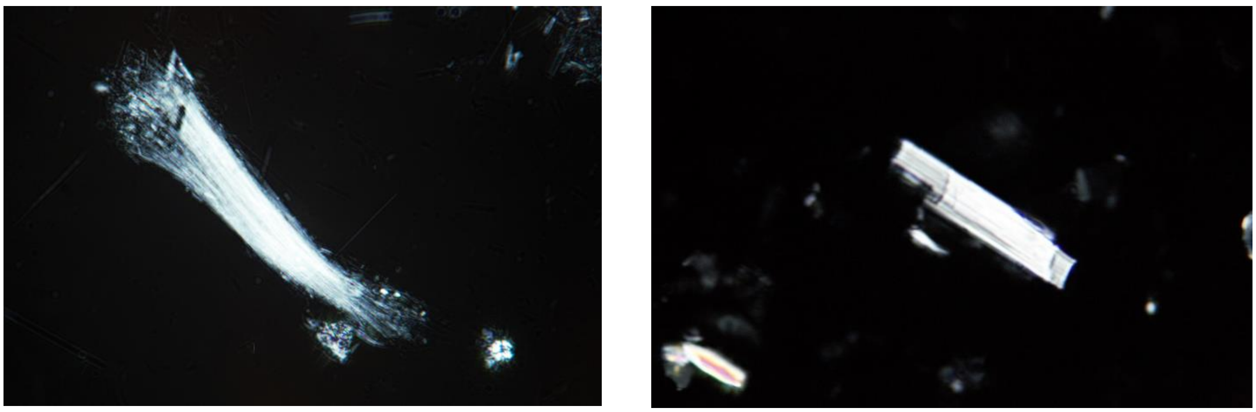


Figure 6. Tremolite. (a)Tremolite asbestos from Metsovo, Greece by PLM, crossed polars. The field of view is approximately 250 µm across and this particle is about 165 µm long. Many tiny, easily separable fibrils make up the particle (b) Tremolite from cosmetic talcum powder. The field of view is also about 250 µm and the particle is 70 µm long and 9 µm wide. It is not a fiber bundle.

The U.S. Environmental Protection Agency (EPA) polarized light microscopy (PLM) method (1993) specifies the characteristics of asbestos, summarized as follows: means aspect ratio (length/width) ranging from 20:1 to 100:1 or higher for fibers longer than 5 micrometers, very thin fibrils, usually less than 0.5 micrometers in width, and 2 or more of the following properties: fibers occurring in bundles, bundles displaying splayed ends, matted masses of individual fibrils and fibers showing curvature. These characteristics are evident in the asbestos shown in Figure 6(a).

The particle shown in Figure 6(b) is bounded by planes that have broken during grinding. It behaves as a single particle optically, so it is **not** composed of smaller fibrils. Its shape, surface morphology, length to width ratio and dimensions are characteristic of cleavage fragments.

If amphibole asbestos is present in cosmetic talc because it was in the ore and processed with the talc, it can be found by PLM. The high tensile strength of asbestos preserves long fibers, and fiber bundles would be expected among the larger particles. Furthermore, distinguishing between anthophyllite-asbestos and talc is straight-forward by PLM. The detection limit of amphibole in

talc by PLM is theoretically limited only by the number of analyses, but practically there is a limit, probably < 0.01%, unless a procedure for concentrating amphibole, such as heavy liquid separation, is employed. PLM cannot be readily used to provide abundances on the basis of numbers of fibers/unit weight.

Summary: The optical photomicrographs of tremolite and anthophyllite found in the expert reports of Drs. Longo and Rigler document the presence of cleavage fragments. Particles labeled as bundles do not have features consistent with that designation.

The January 15, 2019, report of Drs. Longo and Rigler provides many photographs of EMPs labeled by Drs. Longo and Rigler as fibers and most commonly, fiber bundles of amphibole. Some were taken under polarized light and some showed dispersion in n_D= 1.605 oil. The particles labeled as bundles, however, do not display the characteristics of fiber bundles. Their optical properties and shape are consistent with cleavage fragments and inconsistent with asbestos. Their optical properties are those of single crystals, not composite fiber bundles. An example is shown in Figure 7. Furthermore, the data presented in the report are insufficient to differentiate anthophyllite from tremolite, as in one common orientation, tremolite will display parallel extinction, the only distinguishing characteristic mentioned by Drs. Longo and Rigler.

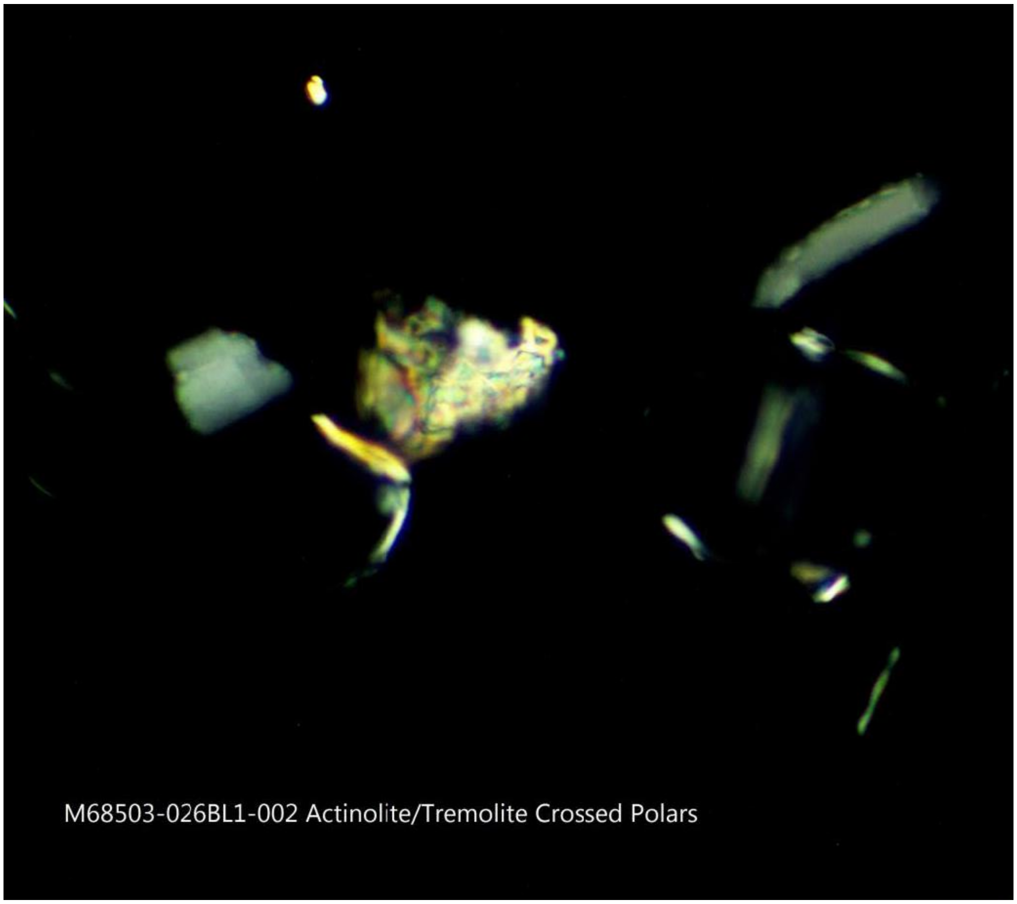


Figure 7. The particle in the upper right-hand corner is labeled as tremolite. The photograph was taken at 200X under crossed polars. The particle is about 40μm long. The uniform first order white interference color is indicative of a single crystal, not a fiber bundle.

2. Transmission electron microscopy (TEM).

Summary: Evidence of fiber bundles is lacking in Drs. Longo and Rigler's *TEM photomicrographs labeled as tremolite and anthophyllite, despite the fact that the particles are called bundles. There is wide range in the width of particles identified as tremolite and anthophyllite and the particle shapes are consistent with a population dominated by cleavage fragments.*

Electron microscopy may be used to detect amphibole in talc. The mineral identity of a particle viewed with an electron microscope is usually decided by particle shape, qualitative chemical composition as established by energy dispersive spectroscopy (EDS also known as EDXA) and atomic structure as determined from zone axis electron diffraction patterns.

The particles examined are usually the smallest in a sample, so bundle structures are less common and the uniformity of width of fibrils in one or sometimes two modes is evident. There are many data sets providing the lengths and widths of amphibole fragments and fibers available for study. In 2016, I published a paper using 35 sets of dimensional data gathered by electron microscopy (Wylie, 2016). Almost all of these data sets are publically available. These data sets demonstrate the ubiquity and abundance of fibrils longer than 5 micrometers with very narrow widths, < 0.3 μm, a characteristic lacking in Drs. Longo and Rigler's tremolite populations and largely absent in the EMP populations labeled as anthophyllite. Furthermore, none of Longo and Rigler's optical microscopy photographs of particles identified by them as anthophyllite demonstrate the presence of bundles of fibers that could disaggregate and form such fiber.

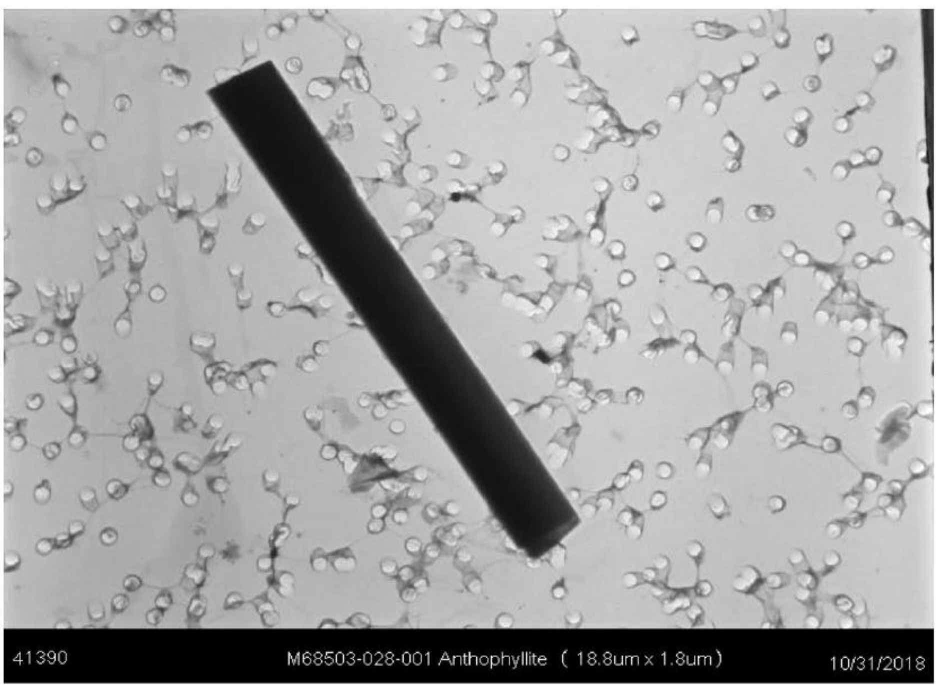


Figure 8. This photograph, taken from the Jan 15, 2019 report of Drs. Longo and Rigler, is reported to be a bundle. It appears to be a single crystal. No criteria are provided for designation as a bundle.

I found three particles out of more than 100 labeled as anthophyllite by Drs. Longo and Rigler that have Length > 8μm and Width < 0.25μm, widths and lengths inconsistent with a normal cleavage fragment population. I would need to see more evidence than that presented in the reports, however, to conclude that they are anthophyllite fibers. Talc, sepiolite, jimthompsonite, clinojimthompsonite and chesterite, all magnesium silicates which occur together, may also form fibers. There has been no evidence presented by optical microscopy that fiber bundles of anthophyllite are present, and it has not been reported from the mine.

3. Aspect ratio.

In general, to determine if a particle is asbestiform, one cannot simply calculate its aspect ratio. Aspect ratio does not tell anything about actual size, only relative size. Aspect ratio has no dimension. Characteristic of both asbestos and cleavage fragment is an increase in aspect ratio with increasing length, i.e., longer EMPs have higher aspect ratios. Differences or similarities in aspect ratio frequencies may, therefore, be due to differences in length frequencies rather than habit.

4. The anthophyllite asbestos-talc controversy.

Summary: Transmission electron microscopy techniques do not readily distinguish between EMPs of talc and anthophyllite. PLM is the most reliable instrument to make this distinction.

From both transmission electron microscopy (TEM) and scanning electron microscopy (SEM), we can obtain dimensions and much information about chemical composition of mineral particles, except their water content. The lack of information on water content has resulted in much confusion about identification of anthophyllite and talc in fiber by electron microscopy. Talc contains about 5% water, and anthophyllite contains 2%. These two minerals have almost the same ratio of MgO to SiO_2, similar electron diffraction patterns in certain orientations and both can form fibers. To confuse the matter more, in the industrial talc from the unusual deposits of Gouverneur, NY, not only are there fibers of mineral talc, but also, in small quantities, fibers formed of intergrowths of talc, anthophyllite and other chain silicates occur, and in eastern Vermont, the Mg silicates chesterite (prismatic), jimthompsonite (prismatic), and clinojimthompsonite (fibrous) have been found in altered serpentinites between the chlorite and the actinolite zones.

In order to distinguish between talc and a fiber of anthophyllite by TEM, one must follow carefully the ISO 10312 TEM method or other approved method that specifies that a fiber should be classified on the basis of morphology and EDXA composition, but also specifies that a list of minerals consistent with that composition be made. A zone-axis selected area electron diffraction (SAED) pattern should be tested for consistency with the crystal structure of the suspected mineral, but also tested for inconsistency with crystal structures of the other minerals of similar composition. If this requirement is not followed, there is no reliable method to tell if a particle is anthophyllite or talc. I did not see any evidence that Drs. Longo and Rigler did such testing, and therefore the distinctions between anthophyllite, talc, and other Mg-silicates may be unreliable.

G. Differences in talc ore deposits and the distinctive and well-studied cosmetic talc deposits in Southern Vermont and Northern Italy.

Summary: Based on their geologic settings, reports from mine geologists and literature descriptions of the ore deposits providing cosmetic talc for Johnson's Baby Powder and Shower to Shower, it is highly unlikely that asbestos could be found in the talc products from these mines.

Talc may form without amphibole or serpentine forming in the ore. Talc without amphibole occurs when temperatures and/or fluid pressures were not high enough for amphibole to form. Talc without serpentine means the temperatures were too high and/or fluid pressure too low for serpentine to form or remain stable. However, talc deposits may form over a range of temperature and fluid pressures accompanied by migration of chemical elements, so amphibole, talc and serpentine can be present together in those circumstances, as explained below.

During metamorphism (the changing of one rock type to another), the set of minerals in a rock is determined by temperature, pressure and the chemical components available.[1] The number of such minerals will normally not be very large. The metamorphic mineral groups most likely to be found in and around talc ore are: chlorite, amphibole, carbonate, sepiolite and serpentine. Quartz, iron oxides and sulfides are known in some places. To minimize these accessory minerals in cosmetic talc products, talc ore is selectively mined for the highest talc content, and then it may be subject to purifying processes such as flotation, magnetic separation and air classification.

There are two types of talc ore deposits:

A. Talc ore formed from alteration of ultramafic rock (Type I). Ultramafic rocks that host talc deposits are much richer in Mg and lower in Si, Ca, K, Al and Na than average crustal rock. There are two types of ultramafic rock that serve as hosts to the talc ore: Serpentinite (Type Ia) and Ultramafic Igneous Rock (dunite, peridotite) (Type Ib). Type Ia includes the deposits of Southern Vermont used in the cosmetic talc products at issue in this litigation.

B. Talc formed from alteration of Mg-rich carbonate rocks (limestone, dolomite) by fluids (Type II). There are three subtypes based on source of fluids: a) Type IIa: regional metamorphism, b) Type IIb: a proximal igneous body, and 3) Type IIc: distal igneous body. The deposits of the Chisone Valley, Italy used in the cosmetic talc products at issue are probably of Type IIc.

[1] During metamorphism, physical and chemical conditions may change rapidly and equilibrium may not be attained. Detailed lattice imaging studies of minerals from these environments by high resolution electron microscopy have revealed a world that can be much more complex than I describe herein, in which it is assumed that particles found in talc products are made up of a single mineral. At the sub-micron scale, amphibole, talc, and a family of single, double, quadruple chain and sheet silicates, and combinations of these, may be intergrown within a single particle. We know this is true from studies of fibrous talc from New York and the talc-amphibole-biopyrobole intergrowths from Chester, Vermont (Veblen and Busek, 1980). However, detailed studies by high resolution TEM are limited and unless evidence is found otherwise, particles in mineral powders are normally considered to be single minerals.

While the minerals associated with talc in both Type I and Type II may be the same (carbonate minerals, chlorite, talc, tremolite, actinolite, serpentine, anthophyllite, olivine, mica and quartz), there is a great deal of variability in presence and abundance of these minerals among talc deposits. There is also variability in the likelihood of finding asbestos associated with talc ore. While the ore from every talc mine or mining district may fit into the classification scheme outlined above, in fact, every deposit is unique in some way(s). In the section below, I will give examples, paying particular attention to the characteristics of deposits mined for cosmetic talc.

1. TYPE Ia: Serpentinite host.

Cosmetic talc ores in Southern Vermont utilized in the talcum powder products at issue are examples of talc ores formed from the alteration of **serpentinite**, a rock composed almost exclusively of the serpentine minerals.

Serpentinite blocks altered during regional metamorphism lose water to surrounding rock and gain Si and CO_2 (among others) from it. This process results in the formation of a series of layers, or zones, dominated by a single mineral encircling the serpentinite. These separate and discrete zones extending outward from the serpentinite core are illustrated in Figure 9, which is taken from the work of Sanford (1982). For the levels of metamorphism known as "greenschist and epidote-amphibolite facies," the amphibole is tremolite-actinolite. For higher levels of metamorphism, the amphiboles will be actinolite, hornblende and anthophyllite.

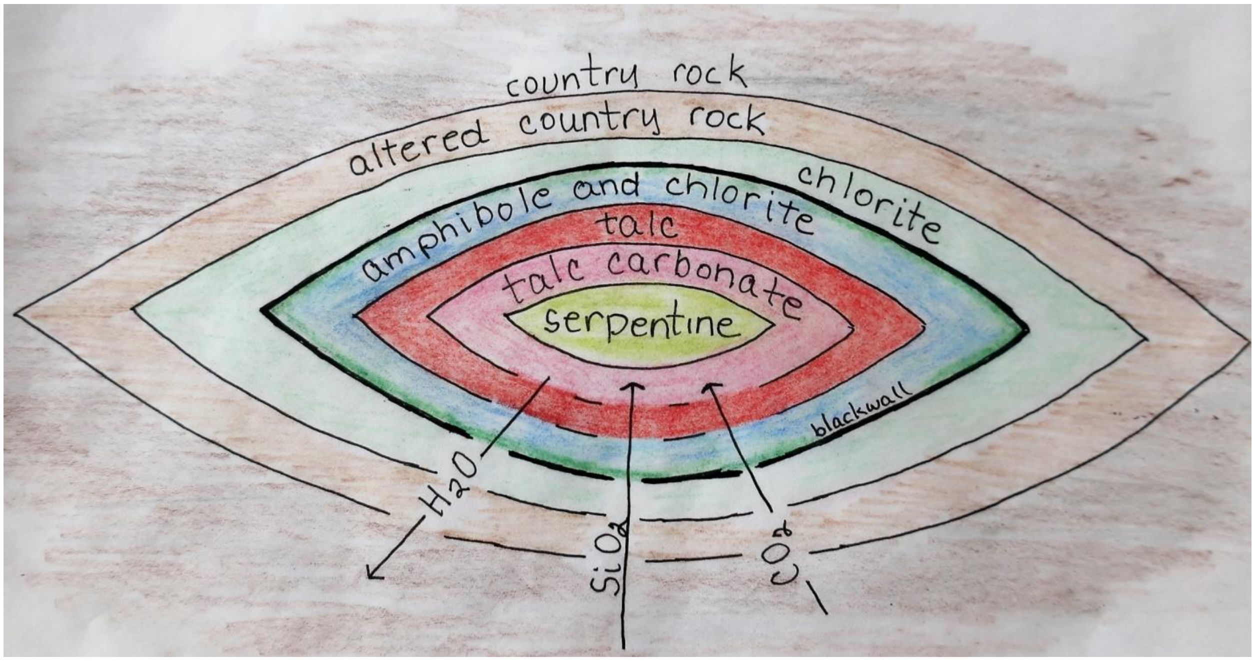


Figure 9. Idealized blackwall metasomatism and the formation of talc from serpentine with chemical exchanges to form talc and talc carbonate from serpentine. Ca and Fe may enter to form amphibole, and, in some instances, Mg will leave. The original boundary before metasomatism is labeled "blackwall." As the serpentinite was heated, water was driven out, and Si was driven in, forming the layers. Cosmetic talc ore is mined from talc zone. The talc carbonate zone is called "grit."

It is the contrast in initial chemical composition of the serpentinite and the surrounding sediment and the availability of water from the serpentinite as it dehydrates during metamorphism that results in the limited mineralogy of these well-defined zones. The transformation is referred to as **black wall metasomatism** for the black color of the chlorite rich zone at the contact with amphibole-chlorite. The chlorite-amphibole/chlorite boundary marks the contact between the original serpentinite and surrounding rock. If amphibole asbestos were to form during metasomatism, it would be most likely deposited by hot fluids escaping the dehydrating serpentinite and well outside the talc zone. In fact, I have seen amphibole asbestos in veins in rock surrounding a large talc free serpentine body in Maryland.

It is common for one or more of the expected blackwall zones to be absent. For example, amphibole may not form at all if temperatures do not rise high enough. Zones may vary a great deal in thickness, from inches to many feet. Only when the talc zone is large and pure enough is it considered ore. Furthermore, although referred to as a single mineral zone, the boundaries are not perfect, and even under careful mining of high-grade talc ore, they might be breached, and trace quantities of amphibole, chlorite or carbonate rock incorporated in talc ore from time to time.

Talc ore formed from serpentinite may contain trace amounts of iron oxides, and/or sulfides, which were part of the original ultramafic rock. If present, the ore may be treated at the mine to remove them.

There is nothing about the mode of formation of this type of talc deposits that favors the formation of asbestos. However, because Mg-rich rocks can be hosts for asbestos, and because asbestos deposits are localized, and because during the 350 million years that have elapsed since these talc deposits formed, periods of faulting may have occurred, each deposit must be considered independently, and regular examination of the mine and mill products is necessary to ensure its absence as mining progresses.

Comments on Windsor County talc deposits:

Dr. Fred Pooley, a distinguished mineral scientist from the Department of Mineral Exploitation, University College Cardiff, UK, visited the talc mines owned by Windsor Minerals in Southern Vermont in 1972. It is my understanding that the ore from this mine was the source of some of the talcum powder products involved in this litigation. He and his team examined the samples he collected from throughout the mine, including ore and foot and hanging wall, and examined them by PLM, X-ray diffraction and transmission electron microscopy. According to his report (Pooley, 1972), **there were no asbestiform amphiboles or chrysotile detected**. Pooley does not report the presence of anthophyllite. Non-asbestiform tremolite and actinolite near the unmined edges of the formation were reported, but amphibole is not disseminated throughout the talc ore. The inner zone is talc high enough in purity to be suitable for cosmetic use. His observations are consistent with the presence of well-defined mineral zones, as would be expected in this type of deposit, enabling the amphibole zones to be avoided in mining or be wasted (discarded as waste rock). The mineralogy of the Windsor mine places it in the “epidote amphibolite facies” of metamorphism as is so well described by the pioneering models in Sanford (1982).

Pooley's detailed descriptions are consistent with published descriptions of talc mines in the Ludlow, Vermont area. The minerals list in the ore from several mines, including the Argonaut mine, by Mindat.org are: apatite, chromite, actinolite, chlorite, magnetite, and magnesite. Chidester et al (1951) describe a large, well-defined mass of actinolite in the Hammondsville mine along the edge of the orebody. Gillson (1927) described the actinolite in talc ore from Windsor County as showing "no effect of stress during deformation" (the lack of asbestos fiber would be consistent). The geologists writing these early reports were well aware of asbestos and the fact that it is not mentioned means it was not observed.

2. Type IIc. Carbonate Host: Distal igneous source.

Cosmetic talc ores in Italy used for Johnson's Baby Powder and Shower to Shower are examples of the alteration of a carbonate by heat and fluids from a distant source. In this category are the Regal, Treasure and Yellowstone mines in southwest Montana, the Italian mines at Chisone Valley, and the talc mines of the Allamore talc district of Texas. The cosmetic talc mines in China may also be of this type. If amphibole is absent, as Van Gosen reports for the Montana deposits (Van Gosen et al., 2004), temperatures were not likely not high enough for formation of tremolite. If tremolite is present but uncommon, as is the case for Italy and Texas, its formation was limited in some other manner, such as the abundance of Ca. Sepiolite fiber is known from Montana, as is fibrous talc (Greenwood, 1998), but these fibers were likely fiber-forming events at temperatures too low for amphibole fiber to form.

There is nothing about the mode of formation of this type of talc deposits that favors the formation of asbestos. However, because Mg-rich rocks can be hosts for asbestos, because asbestos deposits are normally localized, and because it is possible for asbestos to form long after the talc deposit was formed, each deposit must be considered independently, and regular examination of the mine and mill products is necessary to ensure its absence as mining progresses. **However, this type of deposit is not known for associated asbestos.**

Comments on the Val Chisone, Italy, talc deposits.

In 1972, the Department of Mineral Exploitation at University College Cardiff examined hand specimens and powders from an Italian mine, which I understand provided talc product for the talcum powder products at issue (Lightfoot et al., 1972). The team was led by distinguished mineral scientist Dr. Fred Pooley. The samples were studied by PLM, TEM and X-ray diffraction. Pooley and his team found tremolite only in association with carbonate, which could be found as nodules in the ore and elsewhere and wasted. They did not report tremolite in powdered talc ore. They did not report anthophyllite. They did not find tremolite-asbestos. They did not find chrysotile asbestos. They did report fibrous (but not asbestiform) talc.

Greco and Pelizza (1984) report on a visit to the Fontane mine from Val Chisone, Italy. They mention wasting inclusions. Sandrone and Zucchetti (1988) reported on the geology of the Val Chisone (Pinerolo District) cosmetic talc mines. They noted the same accessory minerals reported elsewhere by Dunning et al (1989): zoisite, epidote, rutile, sphene, tremolitic amphibole, quartz and pyrite. **There are no reports of asbestos.** The mineralogy is consistent with the "greenschist" and "epidote amphibolite" levels of metamorphism, where anthophyllite is not expected to form.

3. When is asbestos likely to be found in talc ores?

Summary: The formation of talc does not require or favor the formation of asbestos in the ore.

Asbestos is uncommon, but it is known to favor Mg-rich rocks. While all types of talc deposits can be asbestos-free, some types of talc deposits are more likely to be accompanied by amphibole asbestos than others in the immediate surroundings, although not necessarily in the ore. Amphibole-asbestos is known to be associated with deposits of Type Ib, Type IIa and Type IIb. These generalizations may not apply if there is superimposed on a talc deposit later tectonic events that favor fiber formation, such as faulting or igneous intrusions, but the well-defined planar features of faulting and the presence of igneous rock would be evident during mining and are rare.

Chrysotile forming veins of asbestos has not been reported in cosmetic talc ore to my knowledge.

H. Initial regulation of asbestos.

Summary: In rushing to deal with the asbestos problem of the 1960s, OSHA oversimplified its regulations, and in so doing, confused the distinctions between asbestos and cleavage fragments. Today, all regulatory language specifies the asbestiform habit, and by regulatory policy and practice, regulatory bodies do not regulate cleavage fragment EMPs as asbestos.

In the first regulatory definition of asbestos from OSHA in 1971, the critical distinction of minerals that form in the asbestiform habit was made for serpentine and the amphibole minerals riebeckite and grunerite when they were identified as chrysotile, crocidolite and amosite, terms for specifically designating the asbestiform habit. OSHA did not, however, draw that distinction for the amphiboles tremolite, actinolite and anthophyllite. More concerning is the fact that OSHA neglected other amphiboles that occur as asbestos and cause asbestos related diseases. Instead, OSHA simply defined asbestos as a particle of one of three asbestos types (amosite, crocidolite or chrysotile) or a particle of one of three minerals (tremolite, actinolite or anthophyllite) with a length of greater than 5 microns and an aspect ratio of 3:1 or greater.

This designation of size and shape was selected as part of a counting strategy, principally to eliminate clearly nonfibrous "particulates" from assays and to improve both the precision and accuracy of fiber counting on air filter from an area of known asbestos manipulation. The federal regulatory definition was written without adequate consultation with the mineral experts at the United States Geological Survey or the U.S. Bureau of Mines, and, consequently, it was not mineralogically valid as a description of mineral fiber.

Although the counting criteria were not mineralogically specific for asbestos, its use was not an issue when the definition was employed in measuring levels of exposure only to asbestos known to be present in the dusts. Most in the mining and construction industries never thought that counting criteria could become a definition that transformed ordinary rock fragments into asbestos. In essence, this was not an issue in 1971 when the definition was employed in measuring levels of exposure in areas where asbestos was known to be present. However, monitoring was expanded to areas where both asbestiform and non-asbestiform dusts could be present, and problems with the counting definition emerged.

In 1992, OSHA conducted a review of the health effects of inhalation of non-asbestiform amphiboles. The process included weeks of oral testimony and the submission of written documents from industry, academia, and other regulatory bodies such as NIOSH. I participated in these hearings, and presented data gathered at the University of Maryland and the US Bureau of Mines Research Center in College Park. The work at the University of Maryland was funded by the Bureau of Mines, which was interested in identifying asbestos in mining and differentiating it from the many EMPs commonly found there. The agency determined that "available evidence supports a conclusion that exposure to non-asbestiform cleavage fragments is not likely to produce a significant risk of developing 'asbestos-related' disease" (Federal Register, v. 55, no. 29, February 12, 1990, p. 4939). Consequently, OSHA removed them from the asbestos standard, and to this day, OSHA and The Mining Safety and Health Administration (MSHA) continue to discriminate fragments from mineral fiber (Crane, 2018).

The regulatory landscape since 1971 has changed, and today, differences between amphibole and asbestiform amphibole (i.e., asbestos) are recognized in all regulatory definitions of asbestos. The MSHA states that its regulations apply to "asbestiform hydrated silicates that separate into flexible fibers made of fibrils," and the EPA applies asbestos regulations to "the asbestiform varieties of: Chrysotile (serpentine); crocidolite (riebeckite); amosite (cummingtonite-grunerite); anthophyllite; tremolite; and actinolite" (40 CFR 763.83).

In their 2001 *Toxicology profile for asbestos*, the **U.S. Agency for Toxic Substances and Disease Registry ("ATSDR") states**: "Asbestos is the name given to a group of six different fibrous minerals (amosite, chrysotile, crocidolite, and the fibrous varieties of tremolite, actinolite, and anthophyllite) that occur naturally in the environment… Asbestos minerals consist of thin, separable fibers that have a parallel arrangement. Nonfibrous forms of tremolite, actinolite and anthophyllite also are found naturally. However, because they are not fibrous, they are not classified as asbestos minerals" (2001.09 - ATSDR Toxicological Profile for Asbestos).

The National Institute for Occupational Safety and Health ("NIOSH") published a Roadmap for research on asbestos in 2011 (2011.04 – NIOSH Roadmap). In it, NIOSH defines "asbestos" as "a term used for certain minerals that have crystallized in a particular macroscopic habit with certain commercially useful properties," and "asbestiform" as "a term applied to minerals with a macroscopic habit similar to that of asbestos." NIOSH expressly clarifies that non-asbestiform minerals are not "asbestos" or "asbestos minerals." I served as a reviewer for NIOSH on the first public draft of this document. I believe it introduced the term EMP to make it clear that just because a mineral is elongated and meets the definition of a fiber under asbestos monitoring protocols, it need not be asbestos.

The **U.S. Geological Survey** is the government agency tasked with providing information on rocks and minerals for the nation. In its publication, *Some Facts about Asbestos* (2001.03 – Some Facts about Asbestos), the USGS states: "Asbestos is made up of fiber bundles. These bundles, in turn, are composed of extremely long and thin fibers that can be easily separated from one another. The bundles have splaying ends and are extremely flexible." The document recognizes that this property may not be evident in every particle, presenting difficulties in discriminating among between cleavage fragments and asbestos fibers. "***To resolve this problem, the analyst can compare the shapes of several hundred amphibole particles in the sample with those of***

asbestos reference materials and determine whether a sample is asbestiform with a fair degree of certainty." This is the approach I take in studying amphibole.

The **World Health Organization** (WHO) has also made it very clear that elongated amphibole particles may be asbestiform or cleavage fragments. The International Agency for Research on Cancer (IARC), an agency of the WHO, published a definition of asbestos in 1977, restricting it to the asbestiform habit. "Asbestos is the generic name used for a group of naturally occurring mineral silicate fibres of the serpentine and amphibole series. Government agencies in various countries, and industrial groups, currently characterize six fibrous silicates as 'asbestos': the fibrous serpentine mineral chrysotile and the fibrous amphiboles actinolite, amosite, anthophyllite, crocidolite and tremolite" (IARC, 1977). In 2010, in its monograph on talc, IARC stated: "Asbestos is a commercial term that describes six minerals that occur in the asbestiform habit: actinolite, anthophyllite, chrysotile, grunerite, riebeckite and tremolite. Similarly to talc, these six minerals occur more commonly in a non-asbestiform habit, and may also be elongated without being asbestiform. Actinolite, anthophyllite and tremolite may occur in some talc deposits; when asbestiform, they constitute asbestos and, when not asbestiform, they are referred to as mineral fragments or cleavage fragments" (IARC, 2010 p. 277). I participated in the workgroup that wrote the monograph on talc, and the need to distinguish between these habit forms of amphibole was discussed extensively.

IV. CONCLUSION

There are significant differences between amphibole particles that form as asbestos (asbestos fiber) and those that form from crushing rock (cleavage fragments) including the way they form, the nature of their surfaces, their dimensions, and the occurrence in bundles. Applying only the criteria length > 0.5 µm and length:width of 5:1 or greater as discriminating criteria is scientifically unreliable and invalid.

Talc, a component of cosmetic and industrial talc products, is a mineral that is formed by alteration of Mg-rich rocks. Talc for cosmetic use is mined in only a few places because of the stringent requirements for the product.

Amphibole and serpentine are different but common rock-forming minerals that are hydrated and can be found in Mg-rich rocks. Both occur only rarely as asbestos. Amphiboles that form in the asbestiform habit (e.g., asbestos) exhibit special properties that are different from those same amphiboles that otherwise form in nature. Although talc and asbestos can form in proximity to one another, the formation of talc does not require or favor the formation of asbestos in the ore. Based on their geologic settings, reports from mine geologists, and literature descriptions of the ore deposits used to source the talc for the cosmetic talc products at issue in this litigation, it is unlikely that asbestos occurs in these deposits.

While amphiboles, talc and other minerals may form elongated fragments when they are broken during mining, mineral processing and rock and soil excavation, these fragments are ***not*** "asbestos," or "asbestiform" because they do not have the properties of asbestos. Amphibole populations of asbestos fibers and cleavage fragments have distinctive optical properties, dimensions and habit. There are two types of microscopy used in making this distinction. Polarized light microscopy (PLM) can be used effectively to detect and identify asbestos in talc

products because there are optical properties that are characteristic of cleavage fragments and others that are characteristic of asbestos. Electron microscopy may be used to identify dimensions and habit.

The reports provided by Drs. Longo and Rigler examining the talcum powder products at issue do not present evidence consistent with the optical properties, dimensions or habit of asbestos. Instead, the photomicrographs found in their reports document the presence of cleavage fragments. In addition, the particles Drs. Longo and Rigler have labeled as bundles do not have morphology consistent with that designation (i.e., they are not bundles). As a result, Drs. Longo and Rigler's conclusions are scientifically unreliable.

Further, contrary to the reports provided by Drs. Longo and Rigler, one cannot simply calculate a particle's aspect ratio to determine whether a particle is asbestiform. This is not a scientifically valid approach because aspect ratio does not tell anything about actual particle size, only relative size, and has no dimension. An increase in aspect ratio with increasing length is a characteristic of both asbestos and cleavage fragments. Thus, differences or similarities in aspect ratio frequencies cannot, in isolation, be used to determine whether a particle has an asbestiform habit. In addition, the transmission electron microscopy (TEM) techniques utilized by Drs. Longo and Rigler are scientifically unreliable because they do not readily distinguish between EMPs of talc and anthophyllite. PLM is the most reliable instrument to make this distinction.

In rushing to deal with the asbestos problem of the 1960s, OSHA oversimplified its regulations, and in so doing, confused the distinctions between asbestos and cleavage fragments. As a result, analytical protocols developed for occupational monitoring for airborne fiber during asbestos use for determination of clean air after removal of asbestos from school buildings are overly broad and will produce false positives for mineral fiber when applied to rock powders. Indeed, such regulatory criteria ignore the fundamental characteristics of asbestos. Many naturally occurring minerals will form elongated particles that meet regulatory criteria for fiber even though they do not have the optical properties, dimensions and habit of asbestos. Notably, current regulatory language specifies that asbestos materials are limited to those that form in the asbestiform habit, specifically.

Bibliography

40 C.F.R. 763.83

Argonaut Mine (Argonaut Talc Mine), Ludlow, Windsor Co., Vermont, USA, Mindat.org, https://www.mindat.org/loc-69593.html.

Berry G, Reid A, Aboagye-Sarfp P, de Klerk NH, Olsen NJ, Merler E, Franklin P, Musk AW (2012) Malignant mesothelioma in former miners and millers of crocidolite at Wittenoom (Western Australia) after more than 50 years follow-up. *British Journal of Cancer* 106:1016-1020.

Carbone J, Ly BH, Dodson RF, Pagano I, Morris PT, Dogan US, Gazdar AF, Pass HI and Yang H (2012) Malignant mesothelioma: Facts, myths and hypotheses. *Journal of Cell Physiology* 227:44-58.

Chidester AH, Billings MP and Cady WM (1951) Talc Investigations in Vermont. *USGS Circular* 95

Crane D (2018) OSHA and Elongate Mineral Particles. *Journal of Toxicology and Applied Pharmacology* 361: 165-167.

Dunning FW, Garrard P, Haslam HW and Ixer RA (1989) *Mineral Deposits of Europe Volume 4:* Southwest and eastern Europe with Iceland. Published by the Institute of Mining and Metallurgy and the Mineralogical Society. p. 239.

USEPA (1993) Test Method: Method for the determination of asbestos in bulk building materials. Perkins RL and Harvey BW June 1993, *EPA/600/R-93/116* https://www.nist.gov/sites/default/files/documents/nvlap/EPA-600-R-93-116.pdf.

USEPA (2002) 40 CFR Part 763, Appendix A to Subpart E. http://www2.epa.gov/sites/production/files/documents/2003pt763_0.pdf.

Federal Register, v. 55, no. 29, February 12, 1990, p. 4939.

Gianfagna, A, Andreozzi, GB, Ballirano P, Mazziotti-Tagliani, S, and Bruni, BM (2007) Structural and chemical contrasts between prismatic and fibrous fluoro-edenite from Biancavilla, Sicily, Italy. *Canadian Mineralogist* 45: 249-262.

Gillson JL (1927) Origin of the Vermont talc deposits. *Economic Geology* 22: 246-287.

Greco OD and Pelizza S (1984) The underground Fontane Talc mine: main characteristics of the deposit and exploitation methods. *Boelettino della Associaizione Mineralia Subalpina*. 21.

Greenwood WS (1998) *A mineralogical analysis of fibrous talc*. Master of Science thesis, Department of Geology University of Maryland, College Park MD.

IARC (2010). Talc not containing asbestiform fibres. *IARC Monographs on the Evaluations of Carcinogenic Risk to Humans. Volume 93. Caron Black, Titanium Dioxide, and Talc, pp. 277-413*.

IARC (1977) *IARC Monographs on the Evaluations of Carcinogenic Risk of Chemicals to Man. Volume 14. Asbestos*.

Kerrigan RJ, Candela PA, Piccoli PM, Frank M and Wylie A (2017). Olivine + quartz + water ± HCl at mid-crustal conditions: controls on the growth of fibrous talc as determined from hydrothermal diamond anvil cell experiments. *Canadian Mineralogist* 55(1): 101-113.

Kuryvial RJ, Wood RA and Barret, RE (1974) Identification and Assessment of Asbestos Emissions from Incidental Sources of Asbestos. *Environmental Protection Agency Report*, EPA-650/2-74-087.

Langer AM, Nolan RP, Constantopoulos SH and Moutsopoulos HM (1987) Association of Metsovo lung and pleural mesothelioma with exposure to tremolite-containing whitewash. *The Lancet* 329:965-967.

Lentz T, Rice CH, Succop PA, Lockey JE, Dement JM and LeMaster GK (2003) Pulmonary deposition modeling with airborne fiber exposure data: a study of workers manufacturing refractory ceramic fibers. *Applied Occupational and Environmental Hygiene* 18:278-288.

Lightfoot, JJ Kingston GA, Pooley FD, 8 September 1972, Department of Mineral Exploitation, University College Cardiff report "An examination of Italian Mine samples and relevant powders." 124 pages.

Lippmann, M (2014) Toxicological and epidemiological studies on effects of airborne fibers: Coherence and public health implications. *Critical Reviews in Toxicology* 44(8): 643-695.

Ludlow, Town of Ludlow, Windsor County, Vermont, United States. Mindat.org, https://www.mindat.org/feature-5238156.html.

Pooley FD. Report of the examination of rock samples from the Vermont Mine (Windsor Minerals talc mine) Department of Mineral Exploitation, University College Cardiff, 50 pages.

Rudnick, R.L. and Gao, S. (2003) Vol. 3: The Crust, 3.01—The Composition of the Continental Crust. In: Holland, H.D. and Turekian, K.K., Eds., *Treatise on Geochemistry*, Elsevier-Pergamon, Oxford, 1-64.

Sandrone R and Zucchetti S (1988) Geology of the Italian high quality cosmetic talc from the Pinerolo district (Western Alps). Symposium held in Cagliari, 1988, https://researchgate.net/publication/303834083.

Sanford RF (1982) Growth of ultramafic reaction zones in greenschist to amphibolite facies metamorphism. *American Journal of Science* 282:543-616.

Shedd K (1985) Fiber dimensions of crocidolite from Western Australia, Bolivia, and the Cape and Transvaal Provinces of South Africa. *United States Bureau of Mines Report of Investigation* 8998.

Siegrist and Wylie (1980) characterizing and discriminating the shape of asbestos particles. *Environmental Research* 23: 348-361.

Van Gosen BS, Lowers HA, Sutley SJ, Gent C. (2004). Using the geologic setting of talc deposits as an indicator of amphibole asbestos content. *Environmental Geology* 45: 9220-939.

Veblen and Busek (1980) Microstructures and reaction mechanisms in biopyriboles. *American Mineralogist* 65:599-623.

Veblen, DR and Wylie, AG (1993) Mineralogy of Amphiboles and 1:1 Layer Silicates in *Health Effects of Mineral Dusts*, G.D. Guthrie & B.T. Mossman (eds.). Reviews in Mineralogy, v. 28, Min. Soc. Am., p. 61-131.

Verkouteren JR, and Wylie AG (2002) Anomalous Optical Properties of Fibrous Tremolite, Actinolite and Ferro-Actinolite. *American Mineralogist* 87: 1090-1095.

Virta RL (2001) Some Facts About Asbestos. U.S. Geological Survey. Fact Sheet 012-01.

Weill, et al. (2018) The Monticello Conference On Elongated Mineral Particles. *Toxicology and Applied Pharmacology* 361:1-186.

Wylie, A.G. (2016) Amphiboles: Fibers, fragments and mesothelioma. *Canadian Mineralogist* 54(6): 1403-1435.

Wylie, A.G. (2017) Mineralogy of Asbestos and fibrous erionite. In *Current Cancer Research: Asbestos and Mesothelioma*, Joseph Testa Ed. Springer, Heidelberg pp. 11-41.

Wylie A and Candela P (2015) Methodologies for determining the sources, characteristics, distribution, and abundance of asbestiform and non-asbestiform amphibole and serpentine in ambient air and water. *Journal of Toxicology and Environmental Health, Part B: Critical Reviews* 18: 1-42.

Wylie A and Schweitzer P (1982) The effects of sample preparation and measuring techniques on the shape and shape characterization of mineral particles: The case of wollastonite. *Environmental Research* 27: 52-73.

Additional References:

Scientific Literature

Dunning FW, Garrard P, Haslam HW, and Ixer RA. Eds. (1989) *Mineral Depositions of Europe. Volume 4/5: Southwest and Eastern Europe, with Iceland.* The Institution of Mining and Metallurgy and the Minerological Society.

Veblen DR and Ribbe RH, eds. (1982) *Amphiboles: Petrology and experimental phase relations.* Reviews in Minerology Volume 9B. Mineralogical Society of America..

Deer WA, Howie RA, Zussman J (1997) *Rock-forming Minerals Volume 2B: Double Chain Silicates, 2nd edition.* The Geological Society.

Bailey, SW, ed. (1988) Hydrous Phyllosilicates (exclusive of micas). Reviews in Minerology V. 19. Mineralogical Society of America.

Longo and Rigler Analyses

Longo, Rigler, and Egeland, MAS Project 14-1852 - Below the Waist Application of Johnson & Johnson Baby Powder (Sept. 2017)

Longo and Rigler, Supplemental Expert Report & Analysis of Johnson and Johnson Baby Powder and Valeant Shower to Shower Talc Products for Amphibole Asbestos (Mar. 11, 2018)

Longo and Rigler, The Analysis of Johnson & Johnson's Historical Baby Powder & Shower to Shower Products from the 1960's to the Early 1990's for Amphibole Asbestos (Nov. 14, 2018)

Longo and Rigler, The Analysis of Johnson & Johnson's Historical Product Containers and Imerys's Historical Railroad Car Samples from the 1960's to the Early 2000's for Amphibole Asbestos (Jan. 15, 2019)

Depositions and Exhibits

Deposition of William Longo, Nov. 6, 2018

Deposition of William Longo, Nov. 27, 2018

Deposition of William Longo, Dec. 5, 2018

Deposition of William Longo, Feb. 5, 2019, and Exhibits

Deposition of Rigler, Feb. 6, 2019, and Exhibits

Deposition of William Longo, Oct. 24, 2018

Deposition of William Longo, Oct. 31, 2018

Deposition of William Longo, Jan. 7, 2019

EXHIBIT A

CURRICULUM VITAE
Ann G. Wylie

1. PERSONAL INFORMATION

Ann Gilbert Wylie
Emerita Professor of Geology
University of Maryland
College Park, MD 20742
E-mail: awylie@umd.edu
Phone: (301) 405-4079

Web site: http://www.geol.umd.edu/pages/faculty/WYLIE/wylie.html

Educational:

Ph.D.	1972	Columbia University, New York, New York Major: Economic Geology Minors: Mineralogy, Mining Engineering, and Petrology
B.A.	1966	Wellesley College, Wellesley, Massachusetts Major: Geology

Employment:

a. Academic:

October 2014 – present Professor Emerita

March 1, 2014 – June 30, 2014, Interim Vice President for Information Technology and Chief Information Officer

Oct 2012 – January 2014 Special Advisor to the President for MPower, UMD

Oct 2012 – June 2014 University Marshall

2011-Oct.2012 Senior Vice President and Provost, UMD

2009- 2011 Vice President for Administrative Affairs, UMD

2008 – 2009 Interim Vice President for Administrative Affairs, UMD

2004-2006 Interim Dean of the Graduate School, UMD

2002-2008 Assistant President and Chief of Staff, UMD

2000-2002	Associate Provost, UMD
1998-2000	Acting Associate Dean, College of Computer, Mathematical and Physical Sciences, UMD
1996-1997	Undergraduate Director, Department of Geology, UMD
1992-2014	Professor, Department of Geology, UMD
1990-1994	Associate Chairman and Director of Graduate Studies, Geology Department, UMD
1989-1990	Acting Chairman, Geology Department, UMD
1986-1987	Special Assistant to the Dean for Graduate Studies and Research, UMD
1984-1986	Acting Associate Dean for Research, Graduate School, UMD
1977-1992	Associate Professor, Department of Geology, UMD
1973-1977	Assistant Professor, Department of Geology, UMD
1972-1973	Assistant Professor, Department of Agronomy, UMD
1967-1969 1970-1971	Preceptor, Geology Department, Columbia University
1966-1967	Teaching Assistant, Geology Department, Columbia University

***b. Other Positions*:**

January 1981- August 1981	Mineralogist, U.S. Bureau of Mines,

2. Research, Scholarly, and Creative Activities

a. Books

i. Chapters or Articles in Books:

Gilbert, J. Ann (1967) "Units, Numbers, Symbols and Constants", Encyclopedia of Atmospheric Sciences and Astrogeology, Rhodes Fairbridge (ed.). Reinholt Publishing Company, p. 1049-1062.

Wylie, A.G. (1981) Numerous Mineral Descriptions in Encyclopedia of Mineralogy, K. Frye (ed.). Reinholt Publishing Company.

Steel, E. and A. Wylie (1981) "Mineralogical Characteristics of Asbestos". In Geology of Asbestos Deposits, P.H. Riordon (ed.). Society of Mining Engineers of AIME, p. 93-100.

Candela, P.A. and Wylie, A.G. (1989) Genesis of the Ultramafite-associated Fe-Co-Cu-Zn-Ni deposits of the Sykesville District, Maryland Piedmont. Field Trip Guide T241, International Geological Congress, published by American Geophysical Union.

Invited
Veblen, D.R. and A.G. Wylie (1993) "Mineralogy of Amphiboles and 1:1 Layer Silicates" in Health Effects of Mineral Dusts, G.D. Guthrie & B.T. Mossman (eds.). Reviews in Mineralogy, v. 28, Min. Soc. Am., p. 61-131.

Invited
Wylie, A.G. (1995) "The Analysis of Industrial Mineral Products for Crystalline Silica by Optical and Electron Microscopy: A Literature Review". In: Review Papers on Analytical Methods, Chemical Manufacturers Association.

Invited
Wylie, A.G. and P.A. Candela (1999) "Metallic Mineral Deposits - Chromite". In Geol. of Pennsylvania, Pennsylvania Geol. Survey and Pittsburgh Geol. Survey, Special Publication 1, p.588-595.

Invited
Wylie, A.G. (2017) Mineralogy of Asbestos and fibrous erionite. In *Current Cancer Research: Asbestos and Mesothelioma*, Joseph Testa Ed. Springer, Heidelberg 11-41.

b. Edited publications

Weill P, Chatfield E, Gibbs G, Wylie A, eds. The Monticello Conference on elongated mineral particles, Journal of Toxicology and Applied Pharmacology 367:1-186.

b. Articles in Refereed Journals

Wylie, A.G. and P.J.M. Ypma (1974) "Determination of the Optical Parameters, n and k, of Absorbing Minerals with the Microscope: Isotropic Minerals". Economic Geology 52, p. 1300-1327.

Wylie, A.G. (1979) "Fiber Length and Aspect Ratio of Some Selected Asbestos Samples". Annals of the New York Academy of Science 330, p. 640-643.

Wylie, A.G. (1979) "Optical Properties of the Fibrous Amphiboles". Annals of the New York Academy of Science 330, p. 600-605.

Zoltai, Tibor and A.G. Wylie (1979) "Definitions of Asbestos-related Mineralogical Terminology". Annals of the New York Academy of Science 330, p. 640-643.

Rohl, A.N., A.M. Langer and A.G. Wylie (1979) "Mineral Characterization of Asbestos-Containing Spray Finishes". In Asbestos Materials in Schools: A Guidance Document, Part I, EPA C0090, p. 59-64.

Wylie, A.G. and C. Huggins (1980) "Characteristics of a Potassian Winchite - Asbestos from the Allamoore Talc District, Texas". Canadian Mineralogist 18, p. 101-107.

Siegrist, H.G. and A.G. Wylie (1980) "Characterizing and Discriminating the Shape of Asbestos Particles". Environmental Research 23, p. 348-361.

Campbell, W., C. Huggins and A.G. Wylie (1980) "Chemical and Physical Characterization of Amosite, Chrysotile, Crocidolite and non-fibrous Tremolite for Oral Ingestion Studies by NIEHS". Bureau of Mines Report of Investigation #8452, p. 1-63.

Wylie, A.G. and Peter Schweitzer (1982) "The effects of Sample Preparation on Size and Shape of Mineral Particles: The Case of Wollastonite". Environmental Research 27, p. 52-73.

Shedd, K.B., R.L. Virta and A.G. Wylie (1982) "Are Zeolites Dimensionally Equivalent to Asbestos?" In Process Mineralogy II: Applications in Metallurgy, Ceramics and Geology, R.D. Hagne (ed.). Proceeding of Metallurgical Society of AIME, p. 395-399.

Wylie, A.G., K.B. Shedd and M.E. Taylor (1982) "Measurement of the Thickness of Amphibole Asbestos Fibers with the Scanning Electron Microscope and the Transmission Electron Microscope". Microbeam Analysis Society-Electron Microscope Society of America, Proceedings of the Annual Meeting, Washington, D.C., August (1982) p. 181-187.

Shedd, K.B., R.L. Virta and A.G. Wylie (1982) "Size and Shape Characterization of Fibrous Zeolites by Electron Microscopy". Bureau of Mines Report of Investigation #8674, p. 1-20.

Virta, R.L., K.B. Shedd, A.G. Wylie and J.G. Snyder (1983) "Size and Shape Characteristics of Amphibole Asbestos and Amphibole Cleavage Fragments Collected on Occupational Air Monitoring Filters". In Aerosols in the Mining and Industrial Work Environments Volume 2: Characterization, V.A. Parple and B.H. Kiu (eds.). Ann Arbor Science, p. 633-643.

Wylie, A.G. (1984) "Membrane Filter Methods for Estimating Asbestos Fiber Exposure". In Definitions for Asbestos and Other Health-Related Silicates, ASTM STP 834, B. Levadie (ed.). American Society of Testing and Materials, Philadelphia, p. 105-117.

Wylie, A.G., R. Virta and E. Russek (1985) "Characterizing and Discriminating Airborne Amphibole Cleavage Fragments and Amosite Fibers: Implications for the NIOSH Method", American Industrial Hygiene Association Journal 46, p. 197-201.

Wylie, A.G., R. Virta and J. Segretti (1987) "Characterization of Mineral Populations by Index Particle: Implications for the Stanton Hypothesis". Environmental Research 43, p. 427-439.

Wylie, A.G., Candela, P.A. and Burke, T.M. (1987) "Compositional Zoning in Unusual Zinc-rich Chromite from the Sykesville District, Carroll County, Maryland". American Mineralogist 72, p. 413-423.

Wylie, A.G. (1988) "Relationship between the Growth Habit of Asbestos and the Dimensions of Asbestos Fibers". Mining Engineering, November (1988) p. 1036-1040.

Muller, P.D., Candela, P.A. and Wylie, A.G. (1989) "Liberty Complex: Polygenetic Melange in the Central Maryland Piedmont". GSA Special Paper 228 Melanges and Olistostrome of the U.S. Appalachian, J.W. Horton and N. Rast (eds.), p. 113-135.

Candela, P.A., Wylie, A.G. and Burke, T.M. (1989) Genesis of the Ultramafic Rock-Associated Fe-Cu-Co-Zn-Ni Deposits of the Sykesville District, Maryland Piedmont". Economic Geology 84, p. 663-675.

Wylie, A.G. (1990) "Discriminating Amphibole Cleavage Fragments from Asbestos: Rationale and Methodology". Proceedings of the VIIth International Pneumoconiosis Conference, Pittsburgh, p.1065-1069.

Linder, D.E., Wylie, A.G. and Candela, P.A. (1992) "The Mineralogy and Origin of the State Line Talc Deposit, Pennsylvania". Economic Geology 87, p. 157-165.

Wylie, A.G. and Bailey, K.F. (1992) "The Mineralogy and Size of Airborne Chrysotile and Rock Fragments: Ramifications of Using the NIOSH 7400 Method". American Industrial Hygiene Association Journal 53, p. 442-447.

Wylie, A.G. (1993) "Modeling Asbestos Populations: The Fractal Approach". Canadian Mineralogist 30, p. 437-446.

Wylie, A.G., Bailey, K., Kelse, J. and Lee, R. (1993) "The Importance of Width in Fiber Carcinogenicity and its Implications for Public Policy". American Industrial Hygiene Association Journal 54, p. 239-252.

Wolven-Garrett, A., R.J. Wulf, A.G. Wylie, EL Wynder, J Yourik, B Sakarian, W. Zavadoski, R. Zaaenshi (1995) Talc: Consumer uses and health perspectives: Executive Summary. Regulatory Toxicology and Pharmacology v.21 #2 213-215.

Verkouteren, J.R., Wylie, A.G., Steel, E.B. and Lim, M.S. (1995) “Analysis of the Tremolite/Actinolite series using high precision refractive index measurements,” Proceedings of the 29th Annual Meeting of the MAS, Breckinridge, CO, p.27-28.

Wylie, A.G., Skinner, H.C., Marsh, J., Snyder, H., Garzione, C., Hodkinson, D. and Winters, R. (1997) "Mineralogical Features Associated with Cytotoxic and Proliferative Effects of Fibrous Talc and Asbestos on Rodent Tracheal Epithelial and Pleural Mesothelial cells. Journal of Toxicology and Applied Pharmacology 147, p. 143-150.

Wylie, A.G. (1999) "The habit of asbestiform amphibole: Implications for the analysis of bulk samples”. Advances in Environmental Measurement Methods for Asbestos, ASTM STP 1342, M.E. Beard, H.L. Rooks (eds.), p. 53-69.

Verkouteren, J. R., and Wylie, A.G. (2000) The Tremolite-Actinolite-Ferro-actinolite series: Systematic Relationships among Cell Parameters, Composition, Optical Properties, and Habit and Evidence of Discontinuities. American Mineralogist 85, p.1239-1254.

Wylie, A.G. and Verkouteren, J.R. (2000) “Amphibole Asbestos from Libby, Montana: Aspects of Nomenclature”. American Mineralogist 85, p. 1540-1542.

Verkouteren, J.R., and Wylie, A.G. (2002) Anomalous Optical Properties of Fibrous Tremolite, Actinolite and Ferro-Actinolite. American Mineralogist 87, p. 1090-1095.

Candela, P.A., Crummett, C.D., Earnest, D.J., Frank, M.R. and Wylie, A.G. (2007) Low pressure decomposition of chrysotile as a function of time and temperature. American Mineralogist 92, p.1704-1713.

Schwartz, C.W., Wylie, A.G., Davis, A.P., and James, B.R. (2009). "Column Expansion Testing of Chromium Tailings Subgrade Fills." Contemporary Topics in Ground Modification, Problem Soils, and Geo-Support (Iskander, M., Laefer, D.F., and Hussein, M.H., eds.). Geotechnical Special Publication 187, American Society of Civil Engineers, Reston, VA, pp. 442-449.

Taylor, E, Wylie, A., Mossman, B. and Lower, S (2013) Repetitive dissociation from crocidolite asbestos acts as a persistent signal for epidermal growth factor receptor” Langmuir 29(21) p. 6323-6330.

Wylie, A and P Candela (2015) Methodologies for determining the sources, characteristics, distribution, and abundance of asbestiform and non-asbestiform amphibole and serpentine in ambient air and water. Journal of Toxicology and Environmental Health, Part B: Critical Reviews. 18: 1-42.

Wylie, A.G. (2016) Amphiboles: Fibers, fragments and mesothelioma. Canadian Mineralogist 54(6) 1403-1435.

Kerrigan, RJ, Candela PA, Piccoli PM, Frank M and Wylie A (2017). Olivine + quartz +

water ± HCl at mid-crustal conditions: controls on the growth of fibrous talc as determined from hydrothermal diamond anvil cell experiments. Canadian Mineralogist.

c. Book Reviews Other Articles, and Notes

Invited
Book review of Optical Mineralogy: Theory & Technique by E.G. Ehlers. In: American Scientist, Nov./Dec. (1988).

Invited
Book review of Ultramafic Rocks of the Appalachian Piedmont, GSA Spec. Paper 231, Steven K. Mittwede and E.F. Stoddard (eds.), 103 pages, Economic Geology 85 (1990).

d. Other Publications

Gilbert, Jean Ann (1972) Determination of the Index of Refraction and Coefficient of Absorption Under the Microscope: A New Method and Some of Its Applications. Ph.D. Thesis, Columbia University.

Wylie, A.G., L. Johnson, R. Reichlin, E. Steel, and R. Virta (1977). "Mineralogy and Size Distribution of Asbestos". University of Maryland Electron Microscope Central Facility. Newsletter #5.

Lowry, J. and A.G. Wylie (1979) "Mineralogy and Fiber Size Analysis of Amosite". University of Maryland, Electron Microscope Central Facility Newsletter #7.

Steel, E. and A.G. Wylie (1979) "Characteristics of the Asbestiform Habit". Society of Mining Engineers-American Institute of Mining Engineering Annual Meeting, Tucson. Preprint, p. 1-6.

Invited
Wylie, A.G., K.B. Shedd and M.E. Taylor (1982) "Volume Measurements of Asbestos in the SEM". University of Maryland Electron Microscope Central Facility, Newsletter #9.

Invited
Wylie, A.G. (1988) "The Relationship Between the Growth Habit of Asbestos and the Dimensions of Asbestos Fibers". Society of Mining Engineers Preprint #88-85, p.1-7.

Invited
Wylie, A.G. (1989) "Mineralogical Definitions for Asbestos Fibers and Cleavage Fragments". Report of the Committee on Geology and Public Policy GPP012. Geological Society of America, p. 2-4.

Invited
Wylie, A.G. (1996) "Factors Affecting Risk from Biologically Active Minerals", Proceedings, Mineral Dusts: Their Characterization and Toxicology, Washington, D.C. Society for Mining Metallurgy & Exploration, Littletown, Colorado, Sept. 19-20, 1996, p. 33-46.

Prestegaard, K., Wylie, A.G. and Piccoli, P.M. (1999) Characterization of Grout Samples at Winding Ridge." Power Plant Research Program, Maryland Department of Natural Resources.

Schwartz, C., A.G. Wylie, A. Davis, B. James (2000) "Investigation of the Expansive Behavior of Chromium Tailings: Final Report on Phase II Investigations".

Piccoli, P.M., DeHarde, A., Wylie, A.G., and Prestegaard, K. (2000) "Development of a Grout for the Kempton Mine: Characterization (XRD, Chemical Analyses, and SEM/EPMA Data) of Starting Materials. Power Plant Research Project Report, Maryland Department of Natural Resources.

Weill, D., Chatfield, E, Cox, T, Gamble, J, Gibbs, G., and Wylie, A. (2016) Letter to the Editor in reference to: Hwang et al. The Relationship Between Various Exposure Metrics for Elongate Mineral Particles (EMP) in the Taconite Mining and Processing Industry, Journal of Occupational and Environmental Health, Vol. 11, pp 613-624, Journal of Occupational and Environmental health 12:6 D86-D87. DOI: 10.1080/15459624.2015.1006639

Wylie, A.G., Virta R.L., Shedd, K.B., and Snyder, J.G., 2015, Size and shape characteristics of airborne amphibole asbestos and amphibole cleavage fragments: Digital Repository at the University of Maryland, http://dx.doi.org/10.13016/M2HP87

Wylie, A.G., Schweitzer, P., and Siegrist, H.G., 2015, Size and shape characteristics of amphibole cleavage fragments from milled riebeckite: Digital Repository at the University of Maryland, http://dx.doi.org/10.13016/M2S98X

Wylie, A.G., and Virta, R.L., 2015, Size and shape characteristics of mountain-leather actinolite: Digital Repository at the University of Maryland, http://dx.doi.org/10.13016/M2WT68

Wylie, A.G., and Virta, R.L., 2015, Size and shape characteristics of South African actinolite asbestos (ferro-actinolite): Digital Repository at the University of Maryland, http://dx.doi.org/10.13016/M2S138

Wylie, A.G., and Virta, R.L., 2016, Size and shape characteristics of Indian tremolite asbestos: Digital Repository at the University of Maryland, http://dx.doi.org/10.13016/M21H7S

Wylie, A.G., and Virta, RL 2016, Size distribution measurements of amosite, crocidolite, chrysotile, and nonfibrous tremolite: Digital Repository at the University of Maryland, http://dx.doi.org/10.13016/M2798Z

e. Abstracts and Professional Papers presented

Gilbert, Jean Ann and P.J. Ypma (1969) "The Use of an Electro-Optical Compensator for the Determination of the Optical Properties of Opaque Minerals Under the Microscope", GSA Annual Meeting, Atlantic City, New Jersey.

Siegrist, H.G. and A.G. Wylie (1979) "Characterizing and Discriminating the Shape of Asbestos Particles", GSA Annual Meeting San Diego, California.

Invited

Wylie, A.G. and P. Schweitzer (1980) "The Effects of Grinding on the Shape of Wollastonite Particles". Symposium on Electron Microscopy and X-ray Applications to Environmental and Occupational Health Analysis, Penn State.

Huggins, C., A.G. Wylie and W. Campbell (1980) "Preparation and Selected Properties of Amosite, Chrysotile, Crocidolite and Non-fibrous Tremolite for Use in NIEHS Oral Ingestion Studies". Symposium on Electron Microscopy and X-ray Applications, Penn State.

Rosemeier, R.G., M.E. Taylor and A.G. Wylie (1981) "Low Cost 210K Gain Transmission Electron Microscope Image (TEMI) Intensifier". Electron Microscopy Society of America, Annual Meeting, Atlanta.

Virta, R., K. Shedd, A.G. Wylie and J. Snyder (1981) "Size and Shape Characteristics of Amphibole Asbestos and Amphibole Cleavage Fragments Collected on Occupational Air Monitoring Filters". Proceedings of the International Symposium on Aerosols in the Mining and Industrial Work Environment, University of Minnesota USBM-NIOSH, Minneapolis, Minnesota.

Broadhurst, C.L., Candela, P.A., Wylie, A.G. and Burke, T.M. (1983) "A Geochemical Study of the Host Rocks of the Copper-Iron-Cobalt Ores of Sykesville, Maryland: An Ultramafite-Associated Deposit. Geol. Soc. Am. Natl. Meeting, November, (1983).

Burke, T.M., P.A. Candela, and A.G. Wylie (1985) "Evidence for Detrital Ultramafic Bodies in the Eastern Piedmont of Maryland". Geol. Soc. of America Northeastern Section, March (1985).

Wylie, A.G., P.A. Candela and T.M. Burke (1985) "Genesis of High-zinc Chromite and Associated Cobalt Mineralized Blackwall in the Sykesville District, Maryland Piedmont". Geol. Soc. of Amer. National Meeting, November (1985).

Muller, P.D., Candela, P.A. and A.G. Wylie (1985) "Liberty Complex: Polygenetic Melange in the Central Maryland Piedmont". Geol. Soc. of Amer. National Meeting, November (1985).

Invited
Candela, P.A. and Wylie, A.G. (1987) "The Geology of Radon in the Maryland Piedmont: The Development of a Research Plan". Southwest Geol. Soc. Amer.

Candela, P.A., Wylie, Ann G. and Muller, P. (1987) "Ore Deposits as Tectonic Indicators in Melange Terrane". AGU.

Wylie, A.G., Candela, P.A. and Burke, T.M. (1987) The Genesis of Ultramafite-Associated Fe-Cu-Co-Zn-Ni Deposits of the Sykesville District, Maryland Piedmont". Southeast Geol. Soc. Amer.

Linder, D.E. and Wylie, A.G. (1988) "Zeolites from the Paleozoic Metavolcanic James Run Formation, Piedmont Province, MD" Southeast Geol. Soc. Amer.

Invited
Wylie, A.G. "Discriminating Amphibole Cleavage Fragments from Asbestos: Rationale and Methodology. Abstracts of Communication. VII International Pneumoconiosis Conference, Aug. 23-26,1988. Pittsburgh, NIOSH-ILD-BOM-MSHA-OSHA, p. 124.

Invited
Wylie, A.G. (1989) "Distinguishing Tremolite-Asbestos from Tremolite Cleavage Fragments on a Light Optical and Morphological Basis", VII International Pneumoconiosis Conference Proceeding of Workshop: Hazard Recognition of Mineral Dust. Pittsburgh, NIOSH-ILD-BOM-MSHA-OSHA.

Invited
Wylie, A.G., (1989) Fiber Mineralogy and Identification. Society of Mining Engineers Annual meeting

Wylie, A.G., Linder, D. and Candela, P. (1990) "Sedimentary Features of Appalachian Serpentinites". Geol. Soc. of Amer. National Meeting, Nov. (1990), p. A230.

Invited
Skinner, C. and Wylie, A. (1990) "Fibrous Tremolites". Bloss Symposium, VPI, Blacksburg, Virginia.

Invited
Wylie, A.G. (1992) The Analysis of Industrial Mineral Products for Crystalline Silica by Optical and Electron Microscopy. The Measurement of Crystalline Silica International Symposium, August (1992).

Wylie, A.G. (1993) The Fractal Distribution of the Mass of Asbestos Fiber and its Application to the Analysis of Industrial Minerals. Geological Society of America Annual Meeting, Boston.

Verkouteren, J.R. and Wylie, A.G. (1994) "Anthophyllite, Tremolite, and Actinolite Asbestos: Reference Materials and Optical Properties" Inter/Micro 94, Chicago.

Verkouteren, J.R., Wylie, A.G., Steel, E.B., Lim, M.S. (1995) "Analysis of the Tremolite-Actinolite Series using High Precision Refractive Index Measurements". Microbeam Analysis.

Invited
Wylie, A.G. (1996) Factors Affecting Risk from Biologically Active Minerals. Proceedings Society of Mining, Metallurgy & Exploration Symposium. Mineral Dusts: Their Characterizations and Toxicology. Washington DC 33-46

Invited
Wylie, A.G. (1997) "The Habit of Asbestiform Amphiboles: Implications for the Analysis of Bulk Samples" 1997 Boulder Conference: Advances in Environmental Measurement Method for Asbestos. University of Colorado, Boulder, July 13-17 (1997).

Verkouteren, J.R. and A. G. Wylie (2001) "Microdiffraction Analysis of Fibrous Talc: Asbestos in Crayons". 2001 Denver X-ray Conference, Steamboat Springs, Colorado, USA, August 2, 2001.

Piccoli, P.M., DeHarde, A., Wylie, A.G. (2001) "Recycling coal Combustion Byproducts: a Laboratory Study to Evaluate Grout Formulations for Use in the Kempton Mine Complex, Western Maryland. Geological Society of America, Abstracts with Programs.

Verkouteren, J.R. and A.G. Wylie (2001) "Identification of Tremolite-Actinolite Asbestos". 2001 Asbestos Health Effects Conference, May 24-25, 2001, Oakland, CA.

Verkouteren, J.R., A. G. Wylie, E. Windsor, J. Courny, R. Perkins, T. Ennis (2002) "Powder X-Ray Diffraction for Asbestos Analysis". International Centre for Diffraction Data. Annual Meeting of Members, ICDD Headquarters, Newtown Square, PA, March 20, (2002).

Greenwood, W. and A.G. Wylie (2002) "The Optical Properties and Chemical Composition of Fibrous Talc". ASTM Johnson Conference, July 21-25, Johnson, Vermont.

Verkouteren, J.R., and A.G. Wylie (2002) "A PLM Method for Quantitative Analysis of Amphibole Asbestos in Bulk Materials at 0.01 wt.%". ASTM Johnson Conference, July 21-25, Johnson, Vermont.

Verkouteren, J.R. and A.G. Wylie (2002) "Optical Characteristics and Mineralogy of Environmental Amphibole Asbestos", ASTM Johnson Conference, July 21-25, Johnson, Vermont.

Verkouteren, JR and A G Wylie "Micro-diffraction Analysis of Fibrous Talc: Asbestos in Crayons. Denver x-ray conference.

Crummett, C.D., Candela, P.A., Wylie, A. G., and Earnest, D.J. (2004) "Examination of the Thermal Transformation of Chrysotile by Using Dispersion Staining and

Conventional X-ray Diffraction Techniques". AGU Fall Meeting, V41C-1405.

Earnest, D. J., Candela, P.A., Wylie, A. G., Crummett, C. D, Frank, M. (2004) "Synchrotron Radiation Study of the Kinetics of Dehydration of Chrysotile Fiber". AGU Fall Meeting, V23C-06.

Frank, MR, Candela, PA, Earnest, DJ and Wylie, AG, Wilmot, M, Maglio SJ (2005) Experimental Study of the Thermal Decomposition of Lizardite up to 973 K, GSA Annual Meeting

Kerrigan, RJ, Candela, PA, Piccoli, PM, and Wylie, AG, (2007), Growth of Fibrous Talc and Anthophyllite in the Hydrothermal Diamond Anvil Cell (HDAC), American Geophysical Union Fall Meeting, December 10-14, 2007, San Francisco.

Taylor, ES, **Lower, SK**, **Wylie, AG**, and **Mossman, BT**: The strength of disease: molecular bonds between asbestos and human cells, EOS Trans. AGU, *89*(53): B53B-0479, **2008**.

Schwartz, C.W., Wylie, A.G., Davis, A.P., and James, B.R., (2009), Column Expansion Testing of Chromium tailings Subgrade Fills, International Foundation Congress and Equipment Expo, March 15019, Orlando, FL, 8 pages.

Invited
Wylie, A.G. (2010) Mineralogical Characteristics of Asbestos. GSA meeting, Northeastern/Southeastern sections, Baltimore.

Taylor E, Mossman BT, Wylie AG, Lower SK. (2010) Molecular Methods for the induction of Mesothelioma by Asbestos. GSA meeting Northeastern/Southeastern sections. Baltimore.

Taylor, ES, Lower SK, Mossman, BT and Wylie, AG, 2011. Molecular methods for the Induction of mesothelioma by Asbestos. Biophysics Journal 100. P160a.

Invited
Wylie, A. G. (2013) A Review: Mineralogy and dimensional characteristics of amphiboles from the vermiculite deposit, Rainy Creek Complex, Libby, Montana. GSA meeting Northeastern Section, Bretton Woods, New Hampshire

Invited
Mossman, B.T., Sonali, H, Taylor, E, Lower, S, Dragon, J, bond, J, Wylie, A, and Shukla, A (2013) New Data on How Asbestos Fibers Interact with Cells to Trigger Extracellular Signal-Regulated Protein Kinase, i.e., ERK, Pathways Critical to Toxicity and Disease, 10th International Meeting on fibre/Particle Toxicology, June 407, Dusseldorf, Germany

Wylie, AG and Segrave, A (2019) Can the carcinogenic potential be predicted from metrological properties. ASTM Beard Conference. Denver April.

f. Published Guides for Field Trips:

Wylie, A. and P. Candela (1987) "The Geology of the Maryland Piedmont". 3-day Trip and Guide Book. Department of Geology Annual Trip, October 1987.

Candela, P. and A. Wylie (1988) "The Ultramafite-associated Cu-Fe-Co-Ni-Zn Deposits of the Sykesville District, Maryland Piedmont". Goldschmidt Conference Field Trip, May, 1988.

Candela, P. and Wylie, A. (1989) "Fe-Cu-Co-Ni-Zn deposits of Sykesville, Md." International Geological Congress,T241 July 1989. John Wiley and sons

Candela, P. and A. Wylie (1990) "The Ultramafite-associated Cu-Fe-Co-Ni-Zn Deposits of the Sykesville District, Maryland Piedmont". Goldschmidt Conference Field Trip, May, 1990.

Wylie, AG. (2018) Geology of the Catoctin Mountains, MD. June 9, 2018. Geological Society of Washington Spring Field Trip.

g. Contracts and Grants

Principal Investigator, "Mineralogical Analysis of Road Aggregate Used in Maryland", Maryland Highway Administration, $8,089. November 1974-July 1975.

Co-Principal Investigator, "Optical Microscopic Electron Optical and Microprobe Characterization of Asbestos-Related Materials", U.S. Bureau of Mines, $16,645. December 1975-November 1976.

Principal Investigator, "Serpentines", Faculty Research Board, University of Maryland, $750. Summer 1976.

Principal Investigator, "Optical Microscopic and Electron Optical Characterization of Asbestos-Related Materials", U.S. Bureau of Mines, $11,188. December 1976-November 1977.

Principal Investigator, "Characterization of Asbestos-Related Materials Including Particle Size Distribution, Aspect Ratio and Orientation", U.S. Bureau of Mines, $21,437. December 1977-November 1978.

Principal Investigator, "Mineralogical and Size Distribution Studies of Amphibole Asbestos", U.S. Bureau of Mines, $84,200. April 1979-April 1981.

Principal Investigator, "Dispersion Staining in Optical Mineralogy", Undergraduate Fund for Improvement of Instruction, University of Maryland, $700. 1982.

Principal Investigator, "Quality Control in the Analysis of Asbestos by PLM", $10,000. Sept. 1985-Sept. 1986. Occupational Medical Center.

Principal Investigator "Mineralogy of the Sand Fraction of Aquifer in Northwestern Washington". United States Geological Survey, $2,450. June-October 1986.

Univ. of Maryland General Research Board Semester Research Award, $1,500. 1987.

Mineralogy of Waste Product of Sand and Gravel Processing". Aggregate Industries, $12,000. 1987-1988.

Characterization and Quantification of Fibrous Tremolite in Tremolitic Talc. Southern Talc Company, $17,000. 1989-1990.

Principal Investigator, "Mineralogical Characteristics of Fibrous Talc". R.T. Vanderbilt Company, $23,500. September 1992-December 1997.

Project Director, "Fellowship for the Study of Industrial Talc". R.T. Vanderbilt Company, $33,500. January 1, 1993-December 31, 1997.

Co-Project Director,(with C Schwartz) “Research and Laboratory Testing of Chromium Processing Waste at Dundalk Marine Terminal”, Maryland Department of Transportation, $100,000. December 1996-December 1997.

Co-Project Director (with K Prestegaard and A Amde) “Characterization of Coal Combustion Products and Derived Grout Materials,” Nuclear Power Plant Research Program, Maryland Department of the Environment, $10,000, 1998.

Co-Project Director (with K Prestegaard and A Amde) “Characterization of Coal Combustion Products and Derived Grout Materials, Nuclear Power Plant Research Program, Maryland Department of the Environment, $60,000, 1999

Co-Project Director, (with K Prestegaard and A Amde)"Characterization of Coal-Combustion Products and Derived Grout Material". Power Plant Research Program, Maryland Department of Natural Resources, $40,000, 2000.

Co-Project Director, (with K Prestegaard and A Amde)“Characterization of Coal-Combustion products and Derived Grout Material (supplement)□□□ Power Plant Research Program, Maryland Department of Natural Resources, $60,000, 2000.

Co-Project Director, (with K Prestegaard and A Amde) “A study of the Mineralogical Transformations in Fly-Ash Based Grouts. Maryland Department of Natural Resources, Power Plant Research Program, $30,000, 2000-2001

Co-Project Director (with P Candela) “A study of the thermal transformation of chrysotile”, Ford, GM and Chrysler, $610,000, 2004-2006

h. Fellowship, Prizes and Awards

Seven College Conference of Women's Colleges Scholarship to Wellesley College, 1962-1966.

Wellesley College Scholar, 1966.
Wellesley College B.A., *cum laude*

Faculty Fellowship, Columbia University, 1969-70, 1971-72.

Citation from Governor, State of Maryland, for recognition of assistance in implementation of Title IX in Maryland, 1983.

Butler Prize, Geological Society of Washington, 1989. Given for the best paper read before the Society, 1989.

Distinguished Scholar-Teacher 1994 UMCP.

Fellow Geological Society of America 1990

Honorary Membership in Zeta Nu chapter of Eta Sigma Phi 2011

Outstanding Woman of the Year, President's Commission on Women's Issues, 2012

President's Medal, University of Maryland, 2014

3. Teaching, Mentoring, and Advising

a. Courses taught

<u>Course</u>	Approximate Average Enrollment
Physical Geology	150
Economic Geology	10
Optical Mineralogy	6-10
Ore Microscopy	3
Senior Thesis Research	10
Advanced Topics in Economic Geology	14
Geology of Maryland	6
Geology and Public Policy	15
Environmental Geology	60

b. Advising: Research Direction

i. Undergraduate Thesis (beginning 1980) Major Advisor:

1980 [1]Ed. Jacobsen "Coal Geology of Garrett County, Maryland"

[1]Winner of the AAPG National Undergraduate Research Award

1982 Sharron O'Donnell "Coal Geology of Southwestern Kentucky
Eric Windsor "Shape Characterization of Amphiboles"
Morris Levin "Characterization of Part of the Sykesville Magnetite District by a Magnetometer"
Lyle Griffith "The Use of a Magnetometer in Characterizing the Beasman Prospect, Sykesville, MD."
[2]John Varndell "Heavy Element and Particle Size Relationships in a Sludge Disposal Site, Baltimore, Maryland"
Joe Segretti "Relationship between cytotoxicity and coating of chrysotile fibers"
Mark Beal, A Geologic Evaluation of a Placer Gold Deposit in Southern Fauquier Co., Virginia

1983 Keith Mason "A Preliminary Evaluation of Copper and Cobalt in Conjunction with Iron Mining in the Beasman Prospect of Sykesville, Md."
Michael D. Jones "Chromium in the Soils and Streambeds above the Hunting Hill Serpentinite Body, Montgomery County, Md."
Theresa Baker "Crack Growth in Quartz: The Effects of Chemical Environments"
Mark Hevey "Gas Production and Faulting in Gas Field, Kansas"

1984 Brian Hart "A Potential Field Study of the Magnetite Bearing Deposits of the Central Portion of the Sykesville Mining District"
Katherine Heller "A Reconnaissance Study of the Origin of Small Talc and Serpentine Bodies in the Wissahickon Formation within the Maryland Piedmont"

1987 Dan Linder "Comparison of the James Run with the Sykesville and Morgan Run Formation"
Bethany Baker "Observation on the Geology of Montgomery County from geomagnetic, aeroradioactivity and gravity surveys"
Valerie Gray "Reconnaissance Study on the Source of Gamma Radiation Fluctuation in Eastern Montgomery County"

1988 Tom Davis "Comparative Geothermometry by Using Garnet-Biotite and Fe-Ti Oxides in the Loch Raven Schist

1991 Dan Galasso "Geochemical Prospecting of Heavy Minerals to Determine if a Marker Exists for the Sykesville District of Carroll County, MD"

1994 David Berry "Analysis of Trace Quantities of Amphibole Asbestos Based on the Fractal Model for Mass Distribution"

1995 Bob Schultz "Determination of Asbestos in a Matrix Through Employment of the Fractal Model for Mass Distribution"
Allan Jackson-Gewirtz "A Comparison of Methods of Analysis of Powdered

[2] 2nd Place Winner of the AAPG National Undergraduate Research Award

Samples"
Roberta Winters "Biological Effect of Fiber Size and Mineralogy: The Case of Talc Fibers in Hamster Tracheal Epithelial (HTE) and Rat Macrophage Cells (RMC)"
Mi Lim "Anomalous Optical Properties of Tremolite-Actinolite Fibers"

1996 Tom Biolsi "Effects of absorption and thickness in measuring the index of refraction of blue glass and riebeckite and its application to crocidolite"
Katherine White "X-ray diffraction and optical analysis of picrolite from the State Line Quarry, PA"
Christine Rosenfeld, "Characterization of the Chemistry of the Zeolites Erionite and Mordenite as a Function of Morphology: An SEM/EDS study"

1997 Matt McMillan "Lattice dimensions *vs*. chemical composition and optical properties of tremolite"

1999 Russell Meyer "Lattice Dimensions, chemical composition and optical properties of crocidolite"

ii. Master of Science Degree Awarded

1985 John Ossi, M.S., "A New Petrographic Method For Interpreting Coal-Forming Environments of Deposition"

1988 Robert Virta, M.S., "An Evaluation of the Adequacy of Morphological Data for Determining the Carcinogenicity of Minerals"

1990 Dan Linder, M.S., "The Mineralogy and Origin of the State Line Talc Deposit, Lancaster Co., Pennsylvania"

1991 Tim Rose, M.S., "Petrology and Chemical Variation of Peraluminous Granitic Rocks from the Northern Lobe of the Phillips Pluton, Maine"

1996 Jiang Feng, M.S., "Evidence for compositional variation in phyllite from Carroll and Frederick Counties, MD"

1988 William Greenwood, M.S. "Mineralogical Characteristics of Fibrous Talc"

Diane Hanley, M.S., "Overland flow evaluation of lava flow platform"

1999 Mark Watson, M.S., "Effects of intergrowths on the Physical Characteristics of fibrous Anthophyllite"

2001 Amina DeHarde, M.S., "Characterization of Grouts made from Coal Combustion By-Products: Mineralogy and Physical Properties"

2005 Courtney Crummett, M.S. (co-chair) "Examination of the Thermal decomposition of Chrysotile"

iii. Ph.D.

1991 James Crowley, Ph.D., "Geochemical Study of Playa Efflorescent Salt Crusts and Associated Brines by Using Spectral Reflectance, X-ray Diffraction and Brine Chemical Data"

1999 Martitia Tuttle, Ph.D., "Late Holocene Earthquakes and their Implications for Earthquake Potential of the New Madrid Seismic Zone, Central United States"

4. SERVICE

a. Professional

i. Offices and Committee Membership Held in Professional Organizations

Geological Society of America (Fellow)
Mineralogical Association of Canada
Geological Society of Washington
American Association for the Advancement of Science
American Geophysical Union
Geological Society of America Campus representative (1985-2000)
Chairman, Sigma Xi Graduate Student Research Award Selection Committee, UMCP (1986, 1987)
Mineralogical Society of America: Tellers committee, 1989-1991.
Representative to American Geological Institute, K-12 Education Committee, 1991
Field Trip Chairman, Geological Society of Washington, 1990.
Delegate to AAPG - Geological Society of Washington 1995-96.

ii. Reviewing Activities for Journals and Agencies

American Mineralogist	Environmental Protection Agency
Canadian Mineralogist	U.S. Geological Survey
Science	*Economic Geology*
Environmental Research	Society of Mining Engineers
U.S. Bureau of Mines	*American Industrial Hygiene Journal*
European Journal of Mineralogy	*Critical Reviews in Toxicology*
Periodico di Mineralogia	*Scientific Reports*

National Institute for Occupational Safety and Health

iii. Other Professional Activities

Co-Chairman, New York Academy of Sciences, Workshop #1. Significance of Aspect Ratio in Regulation of Asbestos Fiber Exposure, Conference on the Scientific Basis for the Public Control of Environmental Health Hazards, New York (1978).
Invited Chairman and Organizer of "Asbestiform Minerals Symposium", AIME Annual Meeting (1979) Tucson, Arizona.
Appointed by the U.S. Secretary of Education to the Task Force on Asbestos in the Schools (1980-1984).
Session Chairman, EPA Conference on Monitoring and Evaluation of Airborne Asbestos Levels Following Abatement, March, 1984.
Appointed reference analyst for U.S. Navy Asbestos Analysis Quality Assurance Program (administered by Research Triangle Institute) 1984-1990.
Session Chairman, Economic Geology III, Geol. Soc. of Amer. National Meeting, November 1985.
Member, ASTM Task Group for writing Standard Methods of Analyses of Asbestos by TEM, SEM, Phase Contrast Optical Microscopy and Polarized Light Microscopy. 1985-1990. Author of Polarized Light Microscopy Method (grey sheets).

Expert witness, Occupational Safety and Health Administration hearing on asbestos regulation, 1985, 1990.
Invited participant, Penn. Geol. Survey Conference on Mapping in the Piedmont, 1987.
Expert panel member, EPA, Superfund Bulk Asbestos Method, 1990-1991.
Member IARC Work Group for Talc, Carbon Black, and Titanium Dioxide, Lyon France 2006.
Wellesley College, Class of 1966 Class Officer 1981-86, 2006-11; Annual giving committee 2012-2016
Member, Peer Review Panel, NIOSH, Roadmap for Scientific Research on Asbestos and Other Mineral Fibers, 2007
Testimony, US House Senate, Committee on Environment and Public Work June 12, 2007 and follow-up letter, June 16, 2007
Member, Scientific Advisory Board, National Stone, Sand and Gravel Association 2011-present
Member, Frederick Regional Higher Education Advisory Board 2013-2015
Member, Frederick Center for Research and Education in Science and Technology (CREST) Governing Board 2015-2018
Member Planning Committee for NIOSH EMP workshop on Terminology and Characterization, Paul Middendorf Chair 2016 (rescheduled by CDC to 2017).
Invited participant and member of the Planning Committee, National Academies Workshop on elongated Mineral Particles, May 15-16 2017. (rescheduled to January 2018: cancelled by NIOSH in January)
Co-chair NSSGS/Society of Toxicology Monticello Conference on EMPS, October 2017, Charlottesville, VA
Guest editor. Special issue of Toxicology and Applied Pharmacology: The Monticello Conference.
Invited speaker and session co-moderator, JIFSAN workshop. Asbestos in talc. Nov 2018

c. Selected University of Maryland Service

Chairman, Institutional Review Board (IRB) 1984-1986
Supervisory responsibility for Animal Care and Use Committee and actions (1984-1986)
Chair, General Research Board 1984-1986
Chair, Creative and Performing Arts Board 1984-1986
Member Review Committee for Dean of the College of Computer Mathematical and Physical Sciences 1990
Member, Review Committee for Chair of Department of Economics 1998
Chair, Earth System Science Director Search Committee 1998
` Chair, Limited Enrollment Committee, 2000-2002
Chair, Campus Assessment Working Group, 2000-2002
Chair, Search Committee, Vice President for Research 2002
Chair, Search Committee, Vice President for Administration and Finance, 2004
Chair, UMCP Graduate Council, 2004-2006
UMCP Strategic Planning Steering Committee, Graduate Education Chair, 2008
Chair, UMCP Finance Committee, 2008-2011
Chair, UMCP Sustainability Council 2009-2011
Chair, Student Fee Review Committee 2008-2011
Chair, UMCP Facilities Council, 2011-2012

MPowering the State, UMB-UMCP Steering committee 2011-2013
Carey School of Law Dean Search committee 2013-2014
Facilitator, Leadership Fellows Program, UMCP Advance. 2013-2014
College of Computer, Mathematical and Natural Sciences, University of Maryland, Board of Visitors, 2013-2018
Member. UM Investigation Committee for scholarly misconduct case. 2015
Chair, Investigation Committee to review UM Maryland Industrial Partnership grant to Fifth Quarter Fresh and School of Public Health. 2016

EXHIBIT B

Previous Four Years of Expert Testimony for Ann Wylie, Ph.D.

Dr. Ann Wylie has not testified as an expert at trial or by deposition during the previous four years.